TROPICAL AGRICULTURE

THE OFFICIAL JOURNAL OF THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE

VOL. XII, No. 12. DECEMBER, 1935. PRICE 6d.

CONTENTS.

	PAGE.
Recent Conferences and Congresses	309
The Gold Coast Cacao Industry	311
Le Guarana	312
The Storage and Physiology of Tropical Fruits	313
Recent Investigations on Sugar-Cane and Sugar Cane soils in Trinidad (*Contd.*)	320
A Simple Explanation of the Technological Terms used to express the Results of Sugar-Cane Experiments	333
Reviews	337
Chemical Notes	338
Sugar Notes	339
Trend of the Markets	340

THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE, TRINIDAD, B.W.I.

Cables :: "Stomata." | Phone :: 2183

TROPICAL AGRICULTURE is published monthly at the Imperial College of Tropical Agriculture, St. Augustine, Trinidad, West Indies. Advertisement and subscription rates can be obtained at the College from the Editor, or from the Secretary of the College, 14, Trinity Square, London, E.C.3, England. The Editor will be glad to consider authoritative articles for publication. It is understood that opinions expressed or recommendations made in signed articles or in articles of which the source is named are those of the author and do not necessarily represent the policy or opinion of the College Authorities. Increasing numbers of inquiries are being received from the various parts of the tropics which can be answered only by persons possessed of an intimate knowledge of local conditions. Enquirers should first satisfy themselves that their local Department of Agriculture is not able to supply them with the desired information before communicating with us. Correspondence which will be replied to is invited on all other matters pertaining to tropical agriculture, science and development.

RECENT CONFERENCES AND CONGRESSES*.

THE past summer witnessed several conferences and congresses which afforded further evidence of the progress recently achieved in various branches of agricultural science. The series of meetings of particular interest to us may be said to have begun at Oxford where the Third International Congress of Soil Science was held. This was followed by the Third Imperial Botanical Conference in London, and early in September, by the Sixth International Botanical Congress in Amsterdam. Later in that month, the Fourth Imperial Entomological Conference was summoned in London. It is impossible here to give detailed accounts of these conferences, but an attempt will be made to convey a general impression of what took place.

At Oxford, Sir John Russell, in his presidential address dealt with the contribution of soil science towards improving economic conditions and laid stress in particular on the value of the surveying and mapping of soils as a preliminary of all schemes of agricultural development. In this connection Professor F. Hardy's paper on "Some Aspects of Tropical Soils" may be cited, in that it described quantitative soil profile investigations which, in the Carribbean area, have rendered possible the exact definition of soil best adapted to the growth of several important orchard and field crops, and have made manifest certain soil factors that are definitely harmful to those crops. This aspect of soil work, of which the aims and methods differ widely in different countries, was dealt with by the commission on Soil Genesis, Morphology and Cartography, and by that on the application of soil science to land amelioration. In the Soil Fertility Section of the Congress, considerable interest was displayed in the methods used for estimating the manurial requirements of soils. Professor E. A. Mitscherlich presented the first results of a great cooperative investigation, in which already 120 soils from different parts of the world have been studied, using more than 30 different methods. This investigation is a model of what can be attempted by international cooperation. Professor O. de Vries described the scope of the very large number of field experiments which are being carried out in the Dutch East Indies, and Professor R. A. Fisher, in his demonstration of the principles of the design of field experiments, made clear what is often overlooked, that accuracy alone is not

* Mainly excerpted from reports in *Nature*, Vol. CXXXVI, Nos. 3434; 3436; 3440; 3441; and 3442.

enough unless the *degree* of accuracy is also known. In the Soil Physics Section, Dr. R. K. Schofield introduced a "*p*F" scale which precisely specifies the degree of wetness or dryness of a soil in much the same way as the *p*H scale specifies the degree of acidity or alkalinity. By carefully distinguishing wetting and drying conditions, it was shown that a more rational interpretation could be applied to data on plant wilting and field moisture capacity. In the Chemistry Section, much attention was directed towards the base-exchange properties of soil colloids, particularly from the mineralogical point of view. The very large number of papers dealing with practical soil science emphasised the dominating influence exerted on its development by modern economic conditions. In certain countries soil scientists have almost been driven to produce practical results with insufficient knowledge of the fundamental nature of the soil, and there was a feeling at the Congress that real advancement in pure or applied soil science would depend on the solution of those fundamental problems which so far research workers had been unable to tackle.

The Imperial Botanical Conference was opened by Sir Arthur Hill, who emphasised the ever increasing importance of botanical research in the development of Imperial agricultural resources, not merely with regard to export crops, but also to the food plants of the native and his animals. The study of native crops with the view of obtaining maximum yields under the various local conditions is a work of the greatest national importance which calls for the continued cooperation of botanical and agricultural workers at home and overseas. The Conference confined itself to problems of special Imperial interest, and to the organisation of research. A series of papers on "Pasture Research within the Empire", introduced by Professor R. G. Stapledon, dealt with the importance of 'strain' in pasture plants. The need for safeguarding the original stock of particularly desirable 'strains' or 'groups of strains' was stressed. Dr. Pole-Evans described the natural pasture areas of South Africa to which much damage has already been done by indiscriminate grazing, by burning and by other mal-practices. This was ascribed to a general absence of fundamental knowledge relating to the problems of veld management. A national research programme has now been organised, however, which will deal in particular with problems relating to the general decline in the carrying capacity of the veld due to faulty grazing methods. Mr. Martin Jones dealt with the competition to which the constituents of grassland are subjected by neighbouring plants, and showed how differences in habit or rate of growth lead to the dominance of certain forms or the suppression of others. Grazing by animals is of the greatest importance in this connection, the effects on the development of any particular constituent varying according to the intensity of grazing at any given period. In a session devoted to "Succession of Tropical Forest Types", Dr. Burtt Davy dealt with the evolution of tropical African forest types, Mr. P. Topham described the distribution of forest types in Nyasaland, Mr. W. D. MacGregor of various Nigerian forest types in relation to temperature, rainfall and elevation, and Mr. P. Richards gave a comparative account of three areas of tropical rain forest situated in British Guiana, Sarawak and Nigeria respectively. Of peculiar interest was Mr. C. G. Trapnell's ecological investigation in relation to the application of ecological methods to the study of native agriculture in Northern Rhodesia, which revealed that various native tribes have discovered the association of certain wild plants with certain soil types, and are able to fix on the location and decide on the nature of their cultivated crops in accordance with such observations. These findings would indicate that efforts to advance the prosperity of the country should be directed towards building on the foundations already laid by the native himself, rather than to hazardous introductions or innovations. A session of the Conference was devoted to problems of fruit storage and transport, which have received considerable attention during recent years. The complex problems involved in this type of research are further complicated by the numerous factors which come into play, not only during the storage of fruit, but also while the crop is still on the tree. Various papers describing the work which is being done at Cambridge by the Food Investigation Board, in Canada, New Zealand, Australia and South Africa were read. Considerable interest was evinced in the paper on the storage of tropical fruits submitted by Dr. C. Wardlaw and Mr. R. Leonard and which is published in this issue. In the final session of the Conference attention was directed by Prof. E. E. Cheesman to the pressing need for greater facilities within the Empire for the collection and classification of crop varieties and related species. The work at present is seriously handicapped by the lack of adequate facilities.

The Sixth International Botanical Congress in Amsterdam was attended by about 900 members representing more than 50 countries. From the volume of abstracts of the sectional papers, which proved a useful handbook to the delegates, it is clear that a great variety of subjects of special and general interest were included. Opportunities were also given for joint discussions wherever subjects had an obvious dual interest. An admirable "History of Botany in the Netherlands" and a pamphlet on the Netherlands as an environment to plant life, had been prepared. Various excursions were arranged to botanical laboratories and gardens, the botanical garden in Leyden being a special attraction. Visits were also paid to Baarn, where the extensive collections of pure cultures of fungi was inspected, to the University of Utrecht, and to the Zuyder Zee, where the various processes by which areas submerged by the sea are converted into cultivatable polderland were seen.

The Fourth Imperial Entomological Conference was attended by 27 delegates, each representing a different Dominion, Colony or other area of the British Empire. The papers read and discussed were: locusts and grasshoppers, by Dr. B. P. Uvarov; termites, by Mr. F. P. Jepson; cotton stainers and their control by Mr. W. Allan; sheep blowflies, by Dr. G. D. Morison; the biological control of insect pests, by Dr. W. R. Thompson; pests of stored products, by Prof. J. W. Munro; the need for forest entomologists, with special reference to the pinhole borer problem, by Dr. R. C. Fisher; and plant viruses and their insect vectors, by Dr. K. M. Smith. Mr. Jepson's paper was of particular interest. Termites cause enormous damage, estimated at several millions of pounds sterling in the Empire alone, to crops, forest trees and all structures in which timber is employed in the tropics and subtropics. A very valuable account was given of various methods found effective to render buildings proof against invasion by subterranean as well as by drywood termites. Owing to the contamination of food by the faecal pellets of these insects, which occurs when they infest roof-timbers, food-safes, &c., the varied protozoan and bacterial fauna of their intestines deserves further study. In Ceylon, it is usually in houses attacked by them that cases of sprue develop, and there is reason for suspecting that the contamination of human food by their solid excrement is in some manner associated with the causation of this disease. As a result of this paper the conference recommended the accumulation of data on the financial losses caused by termites to buildings, agriculture and the forest industry, the identity and habits of the species involved, and methods of control. Dr. Uvarov's paper on locusts described recent advances on a subject on which a large amount of coordinated study has been carried out for several years. As a result of an extensive international organisation of which the Imperial Institute of Entomology is the centre it has been possible to trace the movement and breeding of swarms over infested areas in Africa and south-western Asia, and to show that the recent outbreak of the tropical migratory locust, which spread gradually over the greater part of Africa, originated in one or two restricted areas on the Middle Niger, and that the red locust similarly originated in a very few areas in Northern Rhodesia and Tanganyika Territory. Work on the desert locust has not progressed so far, but outbreak centres have been discovered on the coasts of the Sudan and of Baluchistan, and it is almost certain that none exists in the inner deserts of Africa. It will therefore be seen that the international investigations have provided a foundation for a preventive anti-locust policy, by which the outbreak centres can be kept under supervision and incipient outbreaks suppressed.

THE GOLD COAST CACAO INDUSTRY.

[*In* 1933-34 *Mr. C. Y. Shephard, Carnegie Professor of Economics at the Imperial College of Tropical Agriculture visited West Africa at the invitation of the Gold Coast Government to advise on various agricultural economic problems. Excerpts from his report have recently been published in "The Gold Coast Farmer"*.*—ED.]

CACAO is of vital importance to the Gold Coast. It is the principal export, and during the ten years 1923 to 1932 accounted for 77 per cent. of the total value of the exports of domestic produce. Cacao represents 95 per cent. of the exports of agricultural origin. The industry has raised the standard of living far above that of other parts of West Africa and has profoundly affected many phases of native life in the Gold Coast Colony and Ashanti.

A cacao farm is established in a very simple manner: an area of high forest is felled and burned, food crops are planted, and cacao is interplanted at stake. The food crops are cultivated for two to four years, and then the young cacao trees are left to compete with weeds and bush until they come into bearing, when the undergrowth is cleared, and the farm is considered established. Few forest trees remain after deforestation, and shade trees are rarely provided. Those farms which lack windbreaks, overhead shade trees, or natural protection, suffer from the harmattan. Close and irregular planting at 6 to 7 feet is the general rule, the number of trees to the acre being approximately 700 as against 300 in Trinidad and 500 in Grenada.

Methods of cultivation are primitive. The undergrowth is cutlassed in order that pods may not be lost during reaping, but forking, manuring, draining, pruning, trimming and supplying, receive little attention. The high yields of cacao obtained from young cacao have hitherto masked the losses from pests and diseases. The probable consequences of this system are summarised as follows: (*i*) Close planting tends to reduce the growth of bush, to earlier maturity of the cacao tree, and to produce higher yields of cacao in the earlier years. It reduces the need for cultural operations but renders them more difficult. (*ii*) Close planting and the competition of bush tend to produce tall spindly trees having small individual canopies and few lateral branches, and to minimise "wash". (*iii*) The growth of bush tends to retard maturity of the cacao trees. (*iv*) The lack of drains tends to reduce the vigour of the trees on certain types of soil, and the absence of shade exposes the cultivation to sun and wind. Investigations are advocated on questions such as windbreaks, cover crops to smother weeds, the spacing of trees, drainage, manuring and the improvement of growth conditions as a means of reducing the susceptibility of the crop to attack by pests and diseases.

* *Gold Coast Farmer*—May, June, July and August, 1935.

In spite of the primitive system of cultivation adopted in the Gold Coast the yield probably averages between 500 and 600 lb. of cacao per acre. This is at least twice as large as the yield obtained in Trinidad, and equals that obtained by intensive methods in Grenada. High yields in the Gold Coast are, however, due almost entirely to the youth of the cultivation and not, as often assumed, to the much more favourable natural conditions obtaining in that Colony. Earlier records, and estimates of contemporary observers, suggest that yields in Trinidad were slightly larger than in the Gold Coast at comparable ages, while those in Grenada were undoubtedly very much higher than any average which can be claimed for the Gold Coast. Investigations carried out by the College Department of Economics in Trinidad have shown that the yield of a field of cacao increases rapidly from the time the trees commence to bear until the cultivation reaches an age of between 15 and 25 years. Yields subsequently decline rapidly for several years, eventually becoming more or less stable. This sharp rise to the peak value and subsequent fall in yield is characteristic of all cacao fields no matter whether the soil and the methods of cultivation are good or bad. Yields at the peak differ enormously and may be three or four times as large on good and well-cultivated soils as on poor and ill-cultivated soils. The Gold Coast is a comparatively young producer of cacao but appreciable areas have already passed the stage of maximum productivity, and very large areas are at, or are approaching, their peak of production. Thus, in a few years, heavy declines in yield may be anticipated. The experience of every old cacao growing country shows that total production can be maintained over long periods only by the process of establishing new areas to make good the declining efficiency of old cultivation. In the Gold Coast the reduced planting of recent years is likely to be insufficient to counteract the fall in yields on old cultivation. The forecast of a diminishing total production is based on the assumptions that the history of other countries will be repeated in the Gold Coast, and that planting on a large scale will not be resumed. Neither of these assumptions may be correct, but the appearance of certain of the older farms suggests that yields have undoubtedly fallen. In certain areas, such as Bissa, the drop has been marked and general owing to inferior soil and exposed conditions. A comprehensive agricultural economic- and soil-survey is recommended as a means of furnishing evidence regarding the present and future efficiency of the Gold Coast cacao industry.

The total production of cacao in the Gold Coast might be maintained, or even increased, by planting the large tracts of land which are still available in the Western and Central Provinces. Neither labour nor land is a limiting factor. It is feared that the continued destruction of forest for the establishment of cacao farms will eventually produce such arid conditions that the existence of the industry will be threatened. Cacao cultivation, however, accounts for only 1,600 square miles of the 11,000 square miles of forest reputed to have been destroyed. The chief cause of forest destruction has been the shifting cultivation of food crops, and if this could be replaced by a profitable system of fixed cultivation, and if adequate forest reserves were established, there would be little cause to fear a rapid evolution of conditions inimical to cacao.

Cacao prices will largely govern the extension or contraction of the industry. From 1875 to 1920 these were maintained at a very high level despite a sevenfold increase in production. The enormous areas which have been devoted to cacao in West Africa and Brazil in recent years, and the possibility of an extension of the industry in other countries, suggest that the relatively high level of pre-war prices will not be maintained over long periods in the future. A general rise in the real wages of consumers would probably be accompanied by an increased demand for cacao products. The supply of cacao is inelastic and cannot be adjusted rapidly to rising or falling prices. It is therefore probable that cacao prices will exhibit wide variations.

Young cultivation gives higher yields than old cultivation under conditions otherwise similar. The Gold Coast industry is beginning to yield the advantage of youth to other countries. The phase of effortless exploitation is coming to an end, and the Gold Coast farmer must accordingly adjust his standard of living and his methods of cultivation. The individual could adopt with profit the practice of abandoning low yielding old farms and establishing new ones, but there is a limit to the pursuit of this policy by an entire community. Farmers in the more developed districts have to travel far, and to undertake onerous obligations, to obtain suitable land for planting cacao. The time is approaching when more intensive cultivation will be more profitable than the development of new but relatively inaccessible areas.

G. G. G.

LE GUARANA.

Guarana is an alimentary paste prepared by the Indians of northern South America from *Paullinia Cupana*, a sapindaceous tree found in North Brazil. The seeds are not long viable and propagation is usually by cuttings. The tree lives about 40 years, producing 2 kg. of fruit per annum. To prepare the paste the beans are deprived of their tegument which contains a certain amount of saponin and are then crushed in a mortar. The pulp is mixed with cassava flour and is kneaded into a kind of bread which is fermented in water after being wrapped in palm or banana leaves. This fermentation is to eliminate a part of the tannin and caffeine contained in the seed. The paste is then dried in the sun and is used as a form of gruel. Used fresh the paste makes a drink known as mandioca beer. On the Amazon fermentation is dispensed with. The seed is pulverised, fortified by a number of other ingredients, dried in the sun, and rolled into long cylinders in which form it reaches the market. This preparation contains more caffeine than the fermented kinds.—(*Imp. Bur. of Fruit Prod. Hort. Abstracts*. Vol. V, No. 1. Abs. 122, p. 45, 1935.)

THE STORAGE AND PHYSIOLOGY OF TROPICAL FRUITS.

By C. W. Wardlaw and E. R. Leonard,
(*Low Temperature Research Station, Imperial College of Tropical Agriculture, Trinidad, B.W.I.*).

[*Communicated by Sir Geoffrey Evans, C.I.E., M.A., to the Imperial Botanical Conference held in London, August, 1935.*]

For convenience it is proposed to present this account of research undertaken in Trinidad, B.W.I. under two main heads: Part I, concerned with storage problems comprises experiments which are largely empirical in character; in Part II, particular attention is paid to certain problems of respiration in developing, maturing and senescent fruits.

PART I.

Storage Investigations.

The practical results accruing from seven years of low temperature investigation in Trinidad have already been published, and accordingly, in briefly surveying the ground covered, the authors have selected for the purposes of this Imperial Botanical Conference only those aspects which possess the merit of a more general botanical interest, or which illustrate the variety in physiological behaviour encountered during a fairly extensive survey of tropical fruits.

In general, in view of the necessity for overseas transport, the storage physiologist in the tropics must take into consideration questions of temperature—in particular the avoidance of chill effects—the control of humidity and prevention of undue desiccation and the selection of suitable varieties as judged by palatability, keeping quality and susceptibility to fungal wastage. He must also bring to bear a knowledge of field conditions and maturity standards so that fruit may be reaped at such a stage of ripeness as to fulfil storage expectations. The influence of soil and climate, and, in orchard crops, of tree-age and cultivation history, may also assume greater or less importance and in certain circumstances may require special investigation. Not least there is the urgent need that wastage should be curtailed to the minimum. Not infrequently this is due to fungi established as latent infections in the plantations as well as to the inroads of storage pathogens later. The mycological problems which present themselves are accordingly numerous and complex.

An aspect which cannot escape the notice of the investigator working in the moist tropics is the profound manner in which the behaviour of fruits is modified by the impress of environment: in the West Indies, at least, it has become increasingly evident that storage conditions as ascertained in other parts of the tropical or sub-tropical belt must almost invariably be modified before they are applicable to locally-grown fruit.

In illustration of these several aspects of storage investigations with tropical fruits, the following examples are cited.

Bananas.

During the past decade the major aspect of banana investigation has centred round the search for a variety to replace the Gros Michel or Jamaica banana, the chief variety of commerce, whose continuous cultivation over wide areas has virtually been precluded by the onset, in epidemic form, of Panama Disease. It is one of those paradoxes in Nature that the Gros Michel, though highly susceptible to Panama or *Fusarium* Wilt disease, is in all other respects almost uniquely suited to the conditions of bulk stowage and transport required in the extensive Caribbean industry: symmetry of bunch, disposition and size of fingers, uniformity of growth, toughness of skin, resistance to disease and ability to be carried at a temperature sufficiently low to effect a significant control of fungal wastage, combine to make it not easily replaceable by other varieties. Investigations on the keeping quality of possible substitutes, extending over six years, have chiefly served to accentuate the collective advantages possessed by the Gros Michel and the difficulties of obtaining a comparable assemblage in an immune variety. Thus the Lacatan variety is subject to low temperature injury when stored at the Gros Michel transport temperature of 53° F.; it is also considerably more subject to mechanical injury and fungal infection and hence wastage during transport at the required temperature of 58° F. tends to be excessive. The Giant Governor variety, though possessing tougher skin qualities than the Lacatan, likewise is subject to chilling at 53° F. Moreover its genetical constitution is such that fruits must be allowed to reach a stage of "heavy fullness" before being reaped, otherwise abnormal skin colours and loss in flavour become evident during ripening. The Cavendish, Canary or Governor banana behaves in general like the Gros Michel. It is the variety cultivated in the Canary Islands; in Brazil it has become the basis of an extensive industry. Nevertheless, because of the spreading disposition of the individual fruits and their susceptibility to bruising and to storage pathogens this variety falls short of the Gros Michel standard. A note of optimism may be sounded regarding certain hybrids which have been obtained in Trinidad by crossing a wild, seeded variety with the Gros Michel. To an almost surprising degree these combine immunity to Panama Disease derived from the male parent, with a very considerable assemblage of the desirable qualities of the female, the Gros Michel. Thus symmetry of bunch, cold storage behaviour, colour and flavour on ripening are approximately those of the Gros Michel. The first hybrid, known as I.C.1, is open to criticism because it yields occasional seeds: as these are exceedingly hard, pebble-like structures on which even the most avid banana consumer will not desire to engage his dentures more than once, it has not been considered expedient to recommend this fruit to the Trade.

The second immune hybrid, known as I.C.2, is seedless; it shares the Gros Michel characters mentioned above, has very fine texture and flavour, but individual fruits tend to be rather short. From cultural experiments on favourable soil types, however, it has already been ascertained that to some extent this defect can be overcome. To biologists and those interested in the banana industry, the achievement of fundamental importance is that such a close approximation to the Gros Michel can be obtained from appropriate breeding experiments.

Tomatoes.

Tropically-grown tomatoes may be regarded as illustrating the unexpected in storage investigations. Thus it has been ascertained that fruits of several varieties grown under Trinidad conditions have yielded storage records which compare very favourably with those obtained elsewhere. In point of fact when picked full-grown but green not only can Trinidad fruit be kept in cold storage—40° to 47° F.—for 20 to 30 days, but on removal to a higher temperature the fruit remains in good condition for a further eight to ten days. These results have been confirmed over a number of years and are in marked contrast to the rapid degeneration recorded in comparable storage trials with fruit grown outside the tropics.

On this subject some interesting observations have been published by Drs. Kidd and West of the Low Temperature Research Station, Cambridge. In view of the disparity between Trinidad findings and previous English results, storage trials were undertaken by them in which supplies of glasshouse fruit grown during summer and autumn respectively were used: the summer fruit gave results comparable to those obtained in Trinidad; the autumn fruit, on the other hand, was characterised by the poorer keeping quality already mentioned. As to why summer-grown fruit or that obtained under tropical conditions should be more tolerant of low temperatures is not understood.

Avocado Pears.

This fruit, which is native to Central America, is represented in the West Indies by a very considerable range of types. The majority of trees are of seedling origin and so far only a few have been selected, named and used in the propagation of standard types. Prior to investigations at the Low Temperature Research Station in Trinidad, little information regarding the storage requirements of this fruit was available and hence work on a varied assemblage of varieties was necessary. The influences of environment on physiological behaviour during storage is well shown by the avocado pear, such information as was available from investigations undertaken in America being inapplicable to fruit grown under Trinidad conditions.

Genetical and environmental factors are reflected in physiological behaviour. In illustration of this it may be mentioned that, in America, cultivated varieties derived from Mexican types display a higher degree of cold-resistance both in the orchard and during the refrigerated storage of fruit. Again, as the avocado pear is mainly valuable for its comparatively high fat content, chemical analyses of fruits grown under different conditions are of interest both on physiological and utilitarian grounds. It has been ascertained that fruit grown in Trinidad, and presumably elsewhere under moist tropical conditions, has a considerably lower oil content than that produced in Florida and California. In Trinidad, this low oil content is characteristic both of introduced and local varieties.

As an indication of the varied range of materials which had to be considered in preliminary experiments, the following general observations may be quoted. These are based on some 50 seedling "varieties" of avocados which have been subjected to cold storage tests.

(*a*) shape may vary from small sub-spherical fruits to elongated bottle-necked fruits of large size;

(*b*) colours include dark green, pale green, yellowish-green, and purple;

(*c*) the skin may be thick or thin, waxy or dull, rugose or smooth, relatively soft in texture or distinctly woody;

(*d*) flesh colour varies from a medium yellow to pale greenish-white;

(*e*) leaving aside questions of palatability which are difficult to define, but which may range from an insipid, floury to a rich, nutty flavour, the flesh may vary in the matter of oil-content, development of fibre and thickness;

(*f*) variations are also readily apparent in the size and shape of the stone, its proportion to the total weight of the fruit, and the nature of its insertion, *i.e.*, loose or adherent to the flesh.

Experimental observations indicate that this striking variability is closely parallelled by the range in behaviour exhibited by fruits when subjected to refrigerated or gas storage or to a combination of both. The avocado pear, in fact, affords excellent material for physiological investigation, profound differences being apparent in rates of ripening, tolerance of low temperatures and susceptibility to chilling injury, tolerance of gas-storage conditions and liability to fungal wastage. Maturation processes, even at relatively low temperatures, slowly continue so that fruits ultimately become ripe and finally over-ripe. In varieties not sufficiently cold resistant, the metabolic trend is, however, abnormal and chill effects in due course become apparent in the vascular strands and storage parenchyma, the initiation of such changes being closely associated with the onset of ripening. As it became evident in the course of experimental work that only a small number of varieties combine the requisite commercial qualities with adequate cold resistance the practical problem was seen to be essentially one of selection.

Limes.

The storage of limes exemplifies in particular the importance of the humidity factor. In general, limes are more difficult to handle than lemons, being less cold resistant and more subject to wastage through shrivelling. Having determined a suitable storage temperature, the avoidance of desiccation, indeed, becomes the major problem confronting the storage physiologist. The fruits, being of small size and therefore presenting a relatively large transpiration surface, become noticeably shrivelled when they have lost 12 to 14 per cent. of their original weight. As, however, desiccation takes places very rapidly at tropical temperature, 1.5 to 2.0 per cent. per day, the commercial storage life, as limited by the onset of shrivelling, may be seriously curtailed by undue delay whilst fruit is waiting to be graded and packed at high temperatures (approximately 80° F. under West Indian conditions). Speedy handling, protecting of fruits by suitable wrappers —various makes of cellophane and certain waxed papers have proved efficacious—and rapid cooling to 45° F. are essential to the successful marketing of limes.

Certain more purely botanical aspects may be mentioned at this point. The susceptibility of the West Indian lime to Wither-tip Disease has necessitated the breeding of new varieties. By crossing the Philippine lime, which more resembles a small lemon than a lime, with the West Indian variety a number of hybrids, immune or highly resistant to Wither-tip, have been obtained. One of these, known as the T.1 lime, is a fruit of good appearance, juice and oil-content and is now being cultivated and marketed on a not inconsiderable scale. A second hybrid, T.6, possesses less favourable commercial qualities but has proved of interest when studied along with the T.1 hybrid and the parental types. All four exhibit considerable differences in the matter of loss in weight during storage under identical conditions. Thus, weight for weight and grade for grade, the two hybrids, T.1 and T.6 suffer more seriously from desiccation than either of the parents (*i.e.*, the West Indian and Philippine varieties). Again, in the matter of cold-resistance, considerable differences were observed, the Philippine lime proving most resistant and the hybrid T. 6 least. The hybrid T. 1, on the other hand, is apparently more cold-resistant than the West Indian lime. Such variations are interesting in that they indicate the unexpected rearrangement of physiological characters which may result from hybridisation.

Grapefruit.

During the past year the storage of grapefruit has been the subject of special investigation because of the rapidly increasing importance of this crop in the West Indies. Here, again, although ample data are available from experiments conducted in the United States, South Africa, and elsewhere, it has been imperative, because of the relation between environment and keeping qualities, to study Trinidad fruit on its own merits from the outset. In particular, attention has been directed to ascertaining the precise temperatures suitable for short or more prolonged periods in storage, the nature and incidence of chilling, the avoidance of excessive desiccation and the incidence and control of wastage. The behaviour of fruit derived from trees which have suffered from gummosis and root-rot also presents special problems of both practical and academic interest. Various commercial practices, *e.g.*, the ethylene colouring treatment, borax treatment, waxing, &c., which in some countries have become more or less standardised will require careful reconsideration before West Indian fruit can be handled to the best advantage. The striking variations in the keeping quality and susceptibility to disease already observed in fruit from different localities in Trinidad call attention to the need for more intensive investigations in several directions.

Other Fruit and Vegetables.

Various other fruits and vegetables including pineapples, papaws, eggplants, ochroes, granadillas, cauliflowers, peppers, &c., have also been the subject of preliminary experiments in Trinidad, but enough has been said to indicate in a general way the variety of materials available for study and the type of observation, botanical and commercial, forthcoming from the empirical avenue of approach.

PART II.

Respiration in Developing, Maturing and Senescent Fruits.

In undertaking work of a more fundamental nature germane to the central problem of the behaviour of fruit during storage, two courses were open: one was to pursue intensively the physiological and biochemical processes involved in a single fruit, such, for example, as the banana; the other was to make more general use of the considerable range of fruits available, the elucidation of particular aspects being facilitated as far as possible by the selection of whatever material appeared most favourable for the work in hand. Various considerations, including conditions of work and shortage of staff, have led us to adopt the latter method of approach with results which may now be briefly outlined.

The Relation Between External Surface and Respiration.

It has been accepted by plant physiologists that in the development of plant organs the intensity of respiration supplies a general indication of the magnitude of metabolism. In fruits, it has been found that the ontogenetic metabolic drift from adolescence through maturity to death is represented in respiration by a curve of characteristic shape. This shows two high values separated in time: one is initial and represents a high rate of respiration in young fruits; the other, occurring at the onset of senescence is known as the climacteric and is generally associated with the change in colour during ripening.

Despite the drawbacks and limitations presented by respiration studies, this method of investigating metabolic rate continues to be used. It will be

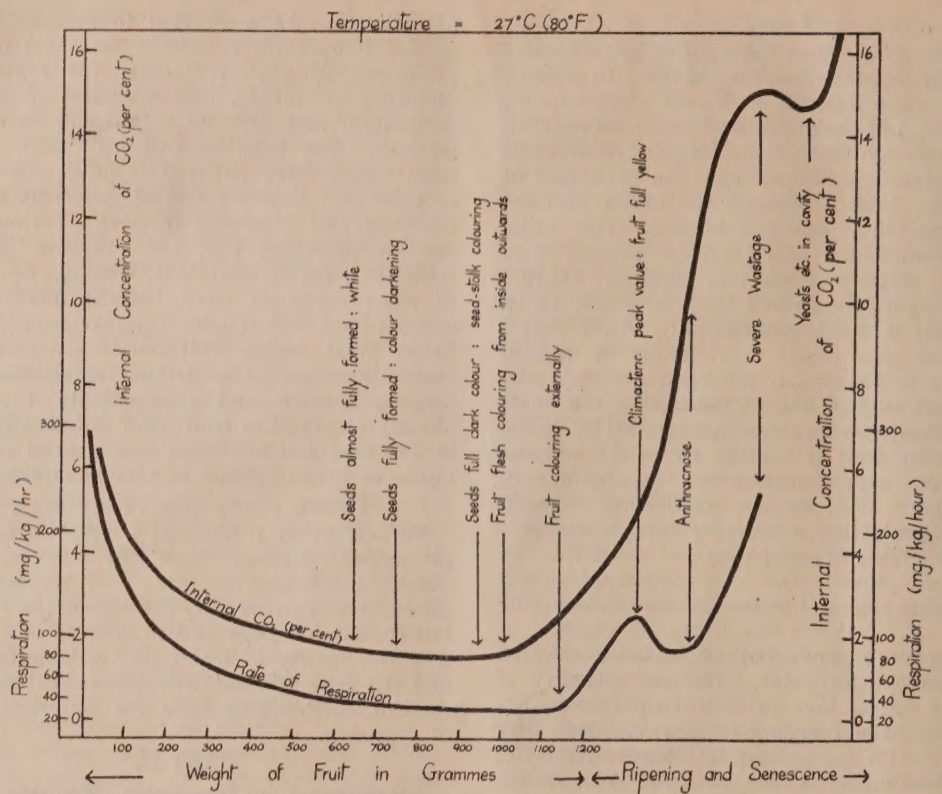
Temperature = 27°C (80°F)
Internal Concentration of CO_2 (per cent)
Respiration (mg/kg/hr)
Seeds almost fully formed : white
Seeds fully formed : colour darkening
Seeds full dark colour : seed-stalk colouring
Fruit flesh colouring from inside outwards
Fruit colouring externally
Climacteric peak value : fruit full yellow
Anthracnose
Severe Wastage
Yeasts etc. in cavity
Internal CO_2 (per cent)
Rate of Respiration
Weight of Fruit in Grammes
Ripening and Senescence

FIG. 1.—*Rate of production and internal concentration of carbon dioxide throughout the development, ripening and senescence of the papaw at 80° F. (semi-diagrammatic).*

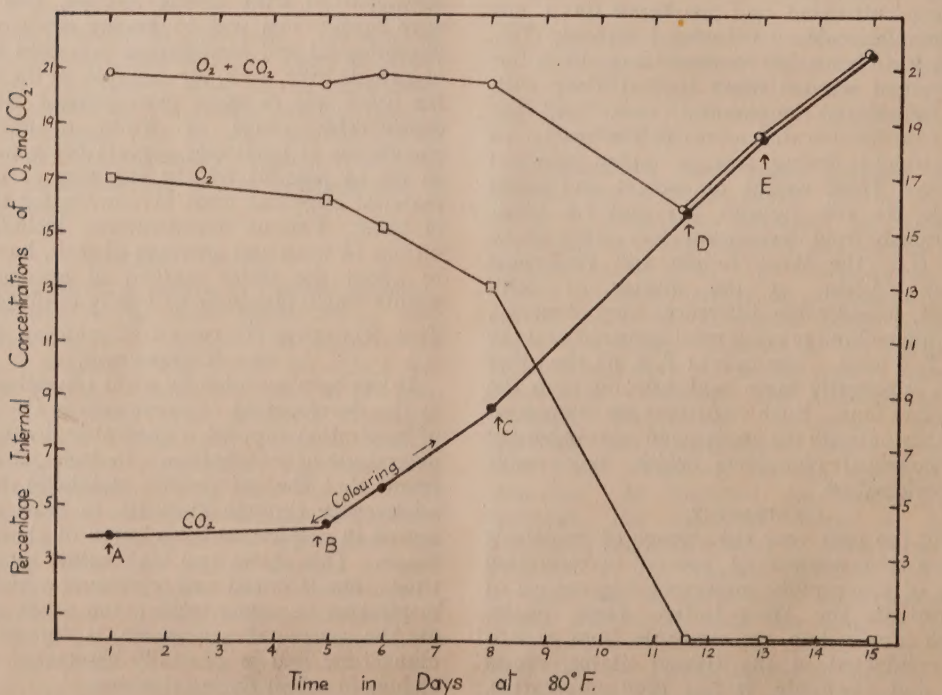

FIG. 2.—*Internal concentration of carbon dioxide, oxygen and carbon dioxide plus oxygen during the ripening of the papaw at 80° F.*

generally admitted, for example, that in the fundamental processes involved in the development, maturation and senescence of plant tissues, serious difficulties have to be overcome in attempting to correlate the rate of respiration at any particular point in time with the major internal changes in progress at that time. Again the phenomenon of the climacteric rise in ripening fruits is not yet fully understood and further, with perhaps a few exceptions, does not appear to be directly correlated in time with the more prominent internal changes as ascertained in biochemical studies. It is hoped that recent studies undertaken in Trinidad may be regarded as affording a clue to the interpretation of certain important aspects of respiration and maturation in fruits.

In studying tropical fruits, the writers are attempting to correlate the measurement of respiration not only with biochemical studies but more especially with the major phases of organographic development through which a fruit passes from the time of fertilisation of the ovules till the fully formed seeds are finally matured and distributed.

As a starting point in these investigations, respiration curves for developing fruits were first examined. In very young fruits the rate of respiration is high and falls off in a regular manner with increase in size, that is, until prior to the rise to the second high (climacteric peak) value. In other words, with qualifications, the smaller the fruit the higher is its rate of respiration. This fact, together with the characteristic shape of respiration curves, suggested that size, involving surface-bulk relationships, might prove an important factor in determining the amount of carbon dioxide liberated during respiration. Actually, further consideration of relevant data showed that this contention could not be accepted in its entirety because of the operation of other complicating factors. Nevertheless, this point of view was useful in that it called attention to the resistance which the epidermis and possibly certain inner tissues offer to the diffusion of gases. To the extent that the skin tissues are found to restrict the movement of carbon dioxide, so also must the interpretation of respiration measurements, *i.e.*, of carbon dioxide liberated superficially, be modified.

Since superficial tissues offer resistance to the diffusion of gases, carbon dioxide outwards and atmospheric gases inwards, it might be inferred—as, in fact, it has been demonstrated by several investigators—that the internal atmospheres of fruits will be characterised by departures from the normal composition of air. Following this line of thought it occurred to us that useful information might be forthcoming from direct measurements of the internal gases of fruits. For this purpose a considerable number of large tropical fruits, either with a cavity or possessing well developed air-spaces, are available. In many of these, no difficulty has been experienced in demonstrating, according to the stage of maturity, very considerable concentrations of carbon dioxide and corresponding reductions in the concentration of oxygen, carbon dioxide and oxygen together as a rule amounting to approximately 21 per cent.

In particular, the papaw, which in large varieties may possess an internal cavity of 900 to 1,200 ccs., has proved especially favourable for investigation and has afforded a coherent account of internal gas relations throughout the life of the fruit. A large accumulation of data is now in hand or in course of publication, and only a brief resumé of certain salient features will be attempted here.

In Fig. 1 the relationship, throughout the life of the papaw between internal carbon dioxide concentrations and respiration as usually measured, has been summarised. The left-hand region of the graph is based on a series of fruits stripped at the same time from a single tree; the individuals selected ranged in size from newly fertilised fruits with a weight of 29 gm. to full-grown, green fruit weighing 1,143 gm. It will be noted that the two curves run closely parallel, high internal values being characteristic of the smaller fruits, low values being the rule prior to the climacteric.

Respiration During Ripening and Senescence.

From the beginning of ripening onwards, respiration rates and internal concentrations of carbon dioxide and oxygen were followed in individual fruits, the curves depicted in Fig. 1 being representative of the average values obtained. It will be observed that at a stage where the fruit is still quite green externally and before the respiration curve has entered on the climacteric rise, the internal concentration of carbon dioxide is already on the increase. This continues steadily during colouring, softening and final maturation of the fruit. Coincident with the onset of skin colouring the respiration curve shows the characteristic rise to the climacteric peak value, this phenomenon being directly related to the increasing internal carbon dioxide concentration. The latter, together with the carbon dioxide which goes into solution in the tissues, may, in fact, be regarded as representing the difference between total cellular respiration and leakage through the fruit flesh and epidermis. In addition to the carbon dioxide in the fruit cavity which can be measured directly, a further proportionate quantity is also present in the flesh tissues.

We next come to a region in the graph, where the two curves no longer run a parallel course. For whereas in the measurement of "external" respiration there is a falling off in the rate of carbon dioxide production after the peak has been passed, no corresponding decrease in the internal concentration of carbon dioxide is apparent. In other words, whereas the characteristic respiration curve for a ripening fruit indicates a considerable decline in the rate of metabolism after the peak value has been passed, it is evident, from the information now available from direct measurements of internal gas concentrations, that this matter requires further investigation.

The observation that the internal carbon dioxide concentration continues to increase while the external liberation of carbon dioxide is falling off indicates that those processes involved in the colouring and softening of fruit are likewise responsible for an increased resistance to the movement of gases.

In the measurement of respiration by the usual methods a time comes when the experiment has to be discontinued on account of fungal wastage, a sharp rise in the rate at which carbon dioxide is liberated being characteristic of this phase. In these papaw studies, however, it was found possible and, in fact, advantageous to continue the recording of internal gas concentrations even after anthracnose spots had developed, and in practice it was quite unnecessary to discard fruits until they had reached an advanced state of decay. When it is recalled that, in the normal course of fruit-fall and decay in a state of nature, the seeds lining the internal cavity will be subject to comparable vicissitudes, the value of such records is apparent.

It is characteristic of the papaw that when a certain stage of ripeness is reached the fruit becomes more or less spotted with the anthracnose fungus, *Colletotrichum gloeosporioides*. Mycological experience shows that this fungus is not a storage pathogen in the usual sense: it is established as a field infection at an earlier period but remains dormant until a certain degree of maturity has been reached. The spots are circular and slightly sunken and for the most part superficial. The chief damage is a destruction of epidermal and sub-epidermal tissues. Later, these spots serve as a means of ingress for rapidly-growing secondary fungi or of wound parasites; thereafter wastage goes on apace so that the flesh is rotted through and the cavity finally becomes infected.

In "external" respiration studies, the first appearance of anthracnose spots is accompanied by a marked rise in the rate of respiration: with the extension of the spots, this continues to a striking degree. The usual interpretation of this phenomenon—the culminating feature of most respiration studies—is that the carbon dioxide is due, not so much to metabolic processes in the fruit, but rather to the active metabolism of the fungi which have become established. Some modification of this view is now necessary. In the case in point, the progress of the fungus through the pulp is slow and the total volume of tissue exploited correspondingly small. The major feature of the disease is, in fact, a destruction of superficial tissue. As active metabolism still continues in the fruit flesh and as the internal concentration of carbon dioxide has risen steadily, a gradient of gaseous concentration of considerable steepness has accordingly been created. Meanwhile the epidermal areas destroyed by fungal activity afford a passage by which increased leakage can take place. Thus the increase in respiration rate coincident with the onset of wastage may now be reassessed as being chiefly referable to leakage through the partly-destroyed epidermis under conditions of high internal carbon dioxide concentrations, the part played by fungal metabolism in the initial stages being of minor importance. Various aspects of respiration after wounding are likewise susceptible of similar interpretation.

In Fig. 2, the curves show the changing concentrations of carbon dioxide, oxygen and carbon dioxide *plus* oxygen during the ripening and senescence of the papaw. With minor variations, the progress of ripening, which has been seen to be accompanied by an increase in the internal concentration of carbon dioxide, is marked by a corresponding decrease in the concentration of oxygen, the sum of the percentages of the two gases in the initial stages being approximately 21 per cent. (Fig. 2: A, fruit picked green; B, commencement of colouring; C, first appearance of Anthracnose Spots; D, severe wastage; E, rapid increase in internal concentration of carbon dioxide due to fungal activity, yeasts, &c., in the fruit cavity.)

Transition to Anaerobic Respiration.

The phase in ripening characterised by the appearance of anthracnose spots is accompanied by notable changes in the relative gas concentrations. From this time onwards the concentration of oxygen falls rapidly while carbon dioxide increases. The sum of the two percentage concentrations, however, now falls to less than 21 per cent., values in the neighbourhood of 16 per cent. being common. These interesting relationships are evidently referable to the increased resistance which the dermal system and/or flesh tissues now offer to the passage of gases. The causes underlying such changes in tissue resistance suggest themselves as the obvious sequel to the present research.

It will be seen that the changes described involve a diminution in the percentage of internal oxygen, a final zero value being obtained. At this stage, when fungal activity has usually become extensive, the concentration of carbon dioxide may actually diminish through increased leakage: this is of short duration, however, the access of rapidly-growing organisms to the central cavity soon resulting in a sharp rise. Where yeasts gain access, the carbon dioxide value may become very high indeed, concentrations of 60 per cent. and over having been recorded. At this stage no further estimation of the fruit's respiratory activity is possible. Viewed from the standpoint of general botany, however, the matter does not rest here. Within the senescent and decaying flesh, the seeds which in the papaw are capable of germination without an intermediate resting period, have still to be liberated and dispersed. The interest of the physiological and ecological problems inseparable from this and the succeeding phases is evident.

In these studies of ripening in the papaw it has been seen that in the later stages of maturation the total demonstrable amount of oxygen in the cavity and, by inference, in the tissues is very small. In other words the final phase of senescence is characterised by a transition from aerobic to anaerobic respiration. The relation which these

conditions of internal gas concentration bear to the destruction of tissues by fungal organisms presents problems of considerable interest. Thus the destructive activity of the anthracnose organism, a definite pathogen, has been found to be delayed until the internal oxygen concentration has fallen to 12 per cent. or less. On the other hand the considerable incidence of more purely saprophytic fungi is not apparent until the tissues are virtually under anaerobic conditions. To what extent the several aspects of loss in resistance to fungal attack are referable to decreased oxygen content or to the depressant action of high concentrations of carbon dioxide is a line of investigation well worth further consideration.

The Initiation of Ripening.

Reverting to Fig. 1, a brief commentary may be offered on the processes involved in the initiation of ripening in fruits—a phenomenon for which no satisfactory account, so far as the writers are aware, has hitherto been forthcoming. In the papaw the central cavity is lined with seeds disposed along five broad placentae. In young fruits the seeds are relatively small and white in colour. In progressively older fruits the seeds, still white, undergo a considerable increase in size. At the point where the seeds have attained more or less to full size, both the respiration curve and that for internal carbon dioxide concentration begin to lie approximately parallel to the horizontal axis, indicating a declining but relatively steady rate of carbon dioxide production. The fully formed seeds now begin to develop a brownish colour and before the climacteric is reached have become quite dark. This represents the completion of seed development, the darkening colour being the visible evidence of the final maturation and induration of the seed coat. At this stage the fruit flesh is quite white and the skin dark green in colour, in marked contrast to the orange-yellow colour of the skin and flesh of the fully ripened fruit. The completion of seed formation as a phase in regional development apparently now acts as the directive stimulus in the initiation of ripening processes. In favourable material such as the papaw it can easily be demonstrated that the very first trace of ripening colour occurs in the fleshy stalks on which the individual seeds are borne; ripening colour is next seen in the placentae; the spread of colour now follows the main vascular tracts. These occupy the tissue between the placentae internally and the furrows externally. That the first evidence of external colour is to be seen in the furrows is in keeping with the scheme outlined. In orderly sequence ripening finally follows the secondary vascular strands, till a uniform orange-yellow colour is present throughout the flesh. The close relation that exists between the onset of ripening and changes in the internal concentration of carbon dioxide is shown in Fig. 1.

Allowing for differences in the construction of the fruit, an essentially similar ripening scheme can be demonstrated in the tomato. In full-grown green fruits, where the seeds have acquired mature seed coats, the first trace of pink or red colour develops in the placentae immediately adjacent to the seed clusters. Colour changes then follow the path of the major vascular strands. In contrast to the papaw, these lie, in the tomato, between the placentae and the external ridges of the fruit. Hence in the tomato, the fact that red colour first appears on the ridges may be taken as confirmation of the scheme outlined.

Other fruits examined confirm the observation that ripening proceeds from the seed or stone outwards to the skin.

In relation to the foregoing observations, a fund of interesting commentary obviously falls to be made concerning the initiation of ripening processes in those fruits such as the banana and bread-fruit which are seedless. This, however, is beyond the scope of the present paper.

Application to Gas-Storage.

Again using the papaw as a medium for the study of the movement of gases, it has been possible by a simple arrangement of apparatus in which a single fruit is maintained in a closed container, to make measurements of the gaseous composition of the fruit cavity and of the container atmosphere simultaneously. During such experiments, in which the carbon dioxide of respiration was not absorbed but was allowed to accumulate, data have been obtained which afford a more precise understanding of the actual conditions prevailing *within* fruits under various gas-storage conditions. It has been shown that the actual concentrations of gases (carbon dioxide, oxygen and nitrogen) present within the fruit, together with the gradients of gaseous concentration created in conjunction with the external atmosphere provided, are profoundly important in determining the rate at which carbon dioxide will be liberated superficially in various circumstances. In the course of these investigations, it has become evident that many of the high rates of respiration recorded when fruits are transferred from one gaseous medium to another bear no relation to the actual state of metabolism at that point, but simply represent readjustments of the several gaseous concentrations. The transition effects, which in some instances may yield strikingly high "respiration" values, are generally of relatively brief duration and can be shown by our system of measurement to be explicable almost entirely in terms of diffusion along gradients. Thus when a papaw is placed under anaerobic conditions, *i.e.*, by supplying the containing vessel with nitrogen till all the oxygen originally present has been displaced, it has been shown that not only is the rate of carbon dioxide liberation greatly accelerated, but also that during the transition phase the fruit likewise respires or liberates oxygen. Since these important aspects of gaseous interchange are accurately defined by the experimental method adopted, it is hoped that the extension of these investigations will materially advance our knowledge of the fundamental processes involved in the gas-storage of fruit.

In Experiment III the effect on yield was investigated of dressings of sulphate of ammonia rising to a maximum of 160 lb. of nitrogen to the acre. Curves of diminishing returns were obtained (Figure II). In Experiment VII, on the calcareous soil, there is under measure the effect of dressings of sulphate of ammonia as large as 420 lb. of nitrogen to the acre. Increasing yields are obtained as the dressing increases to 210 lb. of nitrogen. At the dressing of 420 lb. of nitrogen, however, the gain in yield due to sulphate of ammonia has fallen to zero. Both rise and fall in the gain in yield might be due to chance less than once in 100 times (3). The layout of Experiment VII was in the form of 12 randomised blocks of four treatments.

Similar experiments, with equally heavy dressings of nitrogen, have been laid down on soils deficient in lime. It will be shown in a later paper of this series that on these soils the curves obtained by plotting yield against size of dressing of nitrogen are in every case in accordance with the law of diminishing returns. Only on soils containing free calcium carbonate has an ultimate fall in yield been found to occur.

The gain in yield due to a dressing of 105 lb. of nitrogen in Experiment VII is very small in comparison with that normally obtained on acid soils. The excess of lime in the soil of the experimental area is in all probability exerting a serious adverse effect even on the gain in yield due to the lower dressings of nitrogen.

It appears from the data which have been accumulated that yield of cane increases in accordance with the law of diminishing returns by increasing the dressing of sulphate of ammonia to a limiting value. It is shown in Experiment III that the yield curve approaches a maximum more rapidly in the presence than in the absence of lime. *It is shown in Experiment VII that at dressings of sulphate of ammonia exceeding the limiting value a serious diminution in actual yield can occur on soils containing an excess of free calcium carbonate.*

An Interaction of Lime with Potash in the Presence of Nitrogen.

Effect of Potash on the Ultimate Fall in Yield.

A basal dressing of 70 lb. of nitrogen to the acre, as sulphate of ammonia, was applied to all strips of another of the Latin squares of Experiment V in 1932. One strip in each row was given no additional manurial treatment. A second strip in each row received 110 lb. of K_2O as sulphate of potash. The third strip received 20 lb. of water-soluble P_2O_5 as superphosphate in addition to 110 lb. of K_2O. The disposition of the three strips in each row was decided by random choice. The crop under treatment was the second ratoon. The yield data are recorded in Table XV.

Table XV.—*Effect of potash and phosphate on interaction of lime with nitrogen.*

Yield of Second Ratoons (1932-33) *in tons per acre.*

Basal dressing (all plots).	70 lb. N. per acre in 1932.			
Limestone as plants (1929)	Nil.	½L.R.	L.R.	1½L.R.
No K_2O or P_2O_5 ..	11.61	15.14	16.17	12.21
110 lb. K_2O per acre (1932)	16.70	19.50	19.01	18.33
110 lb. K_2O, 20 lb. P_2O_5 (1932) ..	15.04	19.34	19.41	18.40

In the presence of sulphate of ammonia, alone, the type of yield curve is identical with that recorded for the first ratoons in the previous year on another Latin square. The yield of cane significantly increases with the dressing of lime, until a maximum is attained which can be shown to lie at the lime requirement (3). At dressings greater than the lime requirement a significant fall in yield occurs. *If potash is present with the sulphate of ammonia, yield rises to a maximum, but beyond this maximum there is no significant variation in yield as the dressing of lime increases.*

This interaction of potash with lime in the presence of nitrogen is expressed in graphical form in Figure VII.

In Experiment III it has been shown that potash can exert a beneficial effect on the gain in yield due to lime in the presence of adequate phosphate. The data recorded in Table XV give no evidence that the experimental area was deficient in phosphate at this stage of its history, for the addition of phosphate with potash leads to no further gain in yield under the conditions which obtain. The data show the area to be definitely deficient in potash, however, for this manure leads to a significant gain in yield of 3.86 tons of cane to the acre at dressings of lime not exceeding the lime requirement and to a gain in yield of 6.15 tons at the heaviest dressing of lime. It seems that the additional gain in yield due to potash in the presence of a great excess of lime may be a typical potash effect on an area deficient in potash but containing adequate phosphate. It should be noted, however, that the conditions controlling the interaction of lime with potash in Experiments III and V are not exactly comparable, in that the interaction takes place in Experiment V at a dressing of limestone considerably heavier than that used in Experiment III, whether measured in terms of the lime requirement or as tons of limestone to the acre.

The data recorded in Table XV are mean yields for the plots which were not dressed with pen manure in 1929. The corresponding mean yields for the penmanured and unpenmanured plots have been published elsewhere (1).

Interaction of Lime with Potash and of Potash with Pen Manure.

The three Latin squares of Experiment V were reploughed and replanted in 1933. The pen-manured plots were again given a dressing of this manure at the rate of 20 tons to the acre. An analysis of a representative sample of the pen manure is recorded in Table XII.

All strips in one Latin square were given a basal dressing of 125 lb. of nitrogen as sulphate of ammonia (62½ lb. two months after planting and 62½ lb. eight months after planting) and 20 lb. of water-soluble P_2O_5 as superphosphate. One of the three strips in each row of this square was given no additional manure, one strip 55 lb. of K_2O as sulphate of potash and one strip 110 lb. of K_2O as sulphate of potash. The position of the strip treatments in each row was decided by random choice. The phosphate and potash were applied with the first dressing of nitrogen. The yield data for the plant canes on this square are set out in Table XVI. They give a measure of the effect of increasing dressings of potash on the gain in yield due to increasing dressings of lime, in the presence and absence of pen manure, there being a basal dressing of phosphate and of high nitrogen.

Under the conditions which obtain on this square, the average gains in yield of plant canes due to lime, pen manure and potash are 2.65, 3.06 and 2.06 tons to the acre, respectively. The average gain due to lime might be due to chance less than once in 20 times. The average gains due to pen manure and to potash might be due to chance less than once in 100 times.

The Interaction of Lime with Potash.

In the absence of potash the average gain in yield of plant canes due to lime is 1.81 tons to the acre. In the presence of potash the average gain due to lime increases significantly to 3.50 tons of cane. In like manner the corresponding average gain of 2.48 tons of cane due to potash in the presence of lime is significantly greater than the gain of 0.79 tons in the absence of lime. This interaction of lime with potash might be due to chance less than once in 20 times. *It is in complete accord with the corresponding interaction recorded in Table IX for the second ratoons of Experiment III, in that it has taken place in the presence of a basal dressing of phosphate and on an area deficient in potash.*

One of the most important questions investigated on this Latin square is the effect of size of dressing of potash on the gain in yield due to lime. It is clear from the data set out in Table XVI that there is nothing to choose in this respect between the dressing to the acre of 55 lb. and 110 lb. of K_2O either on the penmanured or unpenmanured plots, *i.e.* the effect of size of dressing between these two limits is not significant. *Under the conditions of the experiment, therefore, a dressing of the order of one cwt. of sulphate of potash to the acre appears adequate to ensure full beneficial effect of the dressing of lime. This conclusion is of practical consequence, for the gain in yield which results more than pays for the cost of a dressing of this size.*

Table XVI.—*Effect of size of dressing of potash on gain in yield due to increasing dressings of lime on penmanured and unpenmanured plots, with basal nitrogen and phosphate. (Interaction of lime with potash and pen manure).*

Yields of Cane in Tons per Acre.

Plant Canes (1933-35).

Basal dressing in 1933.	125 lb. N. and 20 lb. P_2O_5 per acre.							
Pen manure (1929 and 1933).	Nil.				20 tons per acre.			
Limestone in 1929.	Nil.	½ L.R.	L.R.	1½ L.R.	Nil.	½ L.R.	L.R.	1½ L.R.
No K_2O	23.30	23.25	24.98	24.09	25.88	29.20	29.53	27.38
55 lb. K_2O p.a. (1933) ..	24.33	27.00	27.84	28.73	26.44	32.58	28.69	29.72
110 lb. K_2O p.a. (1933) ..	24.70	26.91	26.44	30.00	26.06	30.05	27.38	31.31
Average gain due to potash ..	1.21	3.70	2.16	5.27	0.37	2.11	−1.50	3.13
			3.71				1.25	

Treatment with potash in 1933	K_2O.	No K_2O.	Average.
Pen manure in 1929 and in 1933	29.03	28.00	28.51
No pen manure	26.99	23.91	25.45
Gain due to pen manure ..	2.04	4.09	3.06

Gains in Yield due to Limestone.

Pen manure (1929 and 1933).	Nil.			20 tons per acre.			Average.
Limestone in 1929.	½ L.R.	L.R.	1½ L.R.	½ L.R.	L.R.	1½ L.R.	
Potash in 1933	2.44	2.62	4.85	5.06	1.78	4.26	3.50
No potash	−0.05	1.68	0.79	3.32	3.65	1.50	1.81
Average gain due to lime (all plots)	2.05			3.26			2.65

It should be noted that the yields recorded in Table XVI (and Table XVII) are abnormally low for plant canes in view of the dressings of manures used. The weather conditions which prevailed during the period 1933-35 were definitely unfavourable for good growth.

THE INTERACTION OF POTASH WITH PEN MANURE.

The average gain in yield due to pen manure in the absence of potash is 4.09 tons of plant canes to the acre. In the presence of potash the gain in yield falls significantly to 2.04 tons of cane. This interaction of potash with pen manure might be due to chance less than once in 20 times. *Part of the gain in yield due to pen manure can therefore be attributed to the potash it contains* (Table XII). The results of other experiments laid down in Trinidad are in agreement with this conclusion.

Interaction of Lime with Phosphate and of Phosphate with Pen Manure.

All strips on a second Latin square were given a basal dressing of 125 lb. of nitrogen as sulphate of ammonia (62½ lb. two months after planting and 62½ lb. eight months after planting) and 110 lb. of K_2O as sulphate of potash. One of the three strips in each row of this square was given no additional manure, one strip 20 lb. of water-soluble P_2O_5 as superphosphate and one strip 40 lb. of water-soluble P_2O_5 as superphosphate. The phosphate and potash were applied with the first dressing of nitrogen. The yield data for the plant canes on this square are set out in Table XVII. They give a measure of the effect of increasing dressings of phosphate on the gain in yield due to increasing dressings of lime, in the presence and absence of pen manure, there being a basal dressing of potash and high nitrogen.

In view of the importance of the results a plan of the Latin square is set out in Figure VIII. The plan shows the randomised arrangement of the strips in the rows. The yields of plant canes are entered on each sub-plot. The analysis of variance of the yield data is set out in Appendix II of this paper.

Under the conditions which obtain on this square the average gain in yield of plant canes due to pen manure is 2.96 tons to the acre. It might be due to chance less than once in 100 times. The average gain due to phosphate is 1.27 tons of cane to the acre. It might be due to chance less than once in 20 times.

THE INTERACTION OF LIME WITH PHOSPHATE.

At dressings of lime equal to half the lime requirement, and to the lime requirement, the effect of phosphate on yield is not significant. In the absence of lime, and at the dressing equal to one-and-a-half times the lime requirement, phosphate leads to significant gain in yield. The average loss in yield due to phosphate at the half and full lime requirement is 0.64 tons. The average gain in yield due to phosphate in the absence of lime and at one-and-a-half times the lime requirement is 3.18 tons. The difference in the two average gains might be due to chance less than once in 100 times. A definite depression in the gain in yield due to phosphate therefore occurs on the plots of intermediate lime status. Gain in yield due to phosphate is plotted against size of dressing of lime in Figure IX.

TABLE XVII.—*Effect of size of dressing of phosphate on gain in yield due to increasing dressings of lime on pen-manured and unpenmanured plots, with basal nitrogen and potash. (Interaction of lime with phosphate and pen manure).*

YIELD OF PLANT CANES (1933-35) IN TONS PER ACRE.

Basal dressing in 1933.	125 lb. N. and 110 lb. K_2O per acre.							
Pen manure 1929 and 1933.	Nil.				20 tons per acre.			
Limestone in 1929.	Nil.	½ L.R.	L.R.	1½ L.R.	Nil.	½ L.R.	L.R.	1½ L.R.
No P_2O_5	21.23	24.38	24.42	24.52	26.63	28.41	27.75	24.23
20 lb. P_2O_5 p.a. in 1933 ..	25.55	23.91	24.66	27.80	27.00	26.02	27.47	29.67
40 lb. P_2O_5 p. a. in 1933 ..	23.86	24.42	24.84	25.50	32.16	27.84	25.64	27.19
Average gain due to P_2O_5 ..	+3.48	−0.21	+0.33	+2.13	+2.95	−1.48	−1.19	+4.20

Average Values.

Limestone in 1929.	Nil.	½ L.R.	L.R.	1½ L.R.	Average.
P_2O_5 ..	27.14	25.55	25.65	27.54	26.47
No P_2O_5 ..	23.93	26.39	26.09	24.38	25.20
Gain due to P_2O_5 ..	+3.21	−0.84	−0.44	+3.16	+1.27

Treatment with phosphate in 1933.	P_2O_5.	No P_2O_5.	Average.
Pen manure in 1929 and in 1933 ..	27.87	26.76	27.31
No pen manure	25.07	23.64	24.35
Gain due to pen manure	2.80	3.12	2.96

FIG. VIII.—*Plan of a Latin square of Experiment V, showing a typical set of strip treatments. The yield data give a measure of the interaction of lime with phosphate, in the presence and absence of pen manure, for plant canes of the* 1933-35 *crop.*

The numbers of the main treatments are enclosed in brackets. Yields are expressed as quarters per sub-plot. The sub-plot size is 1/30 acre.

47	46	49	56	31	52	40	37	(c)
(3) 39	(5) 42	(7) 50	(6) 53	(1) 35	(8) 40	(4) 39	(2) 30	(a)
37	35	42	47	50	58	50	41	(b)
49	58	60	55	83	54	75	67	(a)
(7) 53	(8) 66	(3) 52	(4) 60	(6) 88	(5) 86	(2) 77	(1) 84	(c)
77	87	58	75	62	72	71	75	(b)
88	71	45	70	48	51	56	66	(b)
(5) 96	(4) 59	(1) 45	(7) 57	(2) 50	(3) 52	(6) 63	(8) 65	(c)
89	62	45	68	77	66	69	51	(a)
60	56	73	47	90	57	77	51	(c)
(1) 50	(7) 56	(6) 80	(3) 63	(5) 70	(2) 84	(8) 69	(4) 49	(b)
43	54	85	62	58	73	69	60	(a)
64	52	64	75	67	58	53	61	(a)
(4) 82	(3) 58	(2) 67	(5) 87	(8) 79	(7) 61	(1) 66	(6) 58	(c)
90	60	71	72	79	79	67	60	(b)
104	62	92	66	89	80	83	63	(b)
(6) 94	(2) 68	(8) 79	(1) 70	(7) 110	(4) 98	(5) 82	(3) 74	(a)
91	84	67	68	98	110	107	77	(c)
89	77	63	74	95	107	108	77	(b)
(8) 95	(6) 76	(5) 86	(2) 86	(4) 82	(1) 88	(3) 105	(7) 90	(c)
64	84	84	77	74	73	78	113	(a)
59	85	83	91	86	69	96	93	(b)
(2) 56	(1) 67	(4) 71	(8) 89	(3) 90	(6) 77	(7) 90	(5) 84	(a)
63	70	60	79	92	89	83	88	(c)

Main Treatments (Limestone in 1929. Pen manure in 1929 and in 1933).

(1) Nil.
(2) ½ L.R. (8 tons ground limestone per acre).
(3) L.R. (16 tons ground limestone per acre).
(4) 1½ L.R. (24 tons ground limestone per acre).
(5) 20 tons pen manure per acre.
(6) ½ L.R. and 20 tons pen manure.
(7) L.R. and 20 tons pen manure.
(8) 1½ L.R. and 20 tons pen manure.

Strip Treatments (in 1933).

(*a*) No superphosphate.
(*b*) 1 cwt. superphosphate per acre.
(*c*) 2 cwts. superphosphate per acre.

Basal Treatments to all plots (1933-34).

6 cwts. sulphate of ammonia per acre.
2 cwts sulphate of potash per acre.

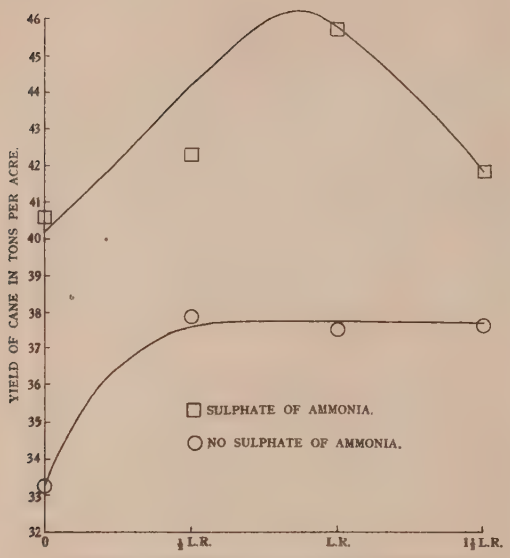

FIG. VI.—EFFECT OF INCREASING DRESSINGS OF LIME ON YIELD IN THE PRESENCE AND ABSENCE OF SULPHATE OF AMMONIA.

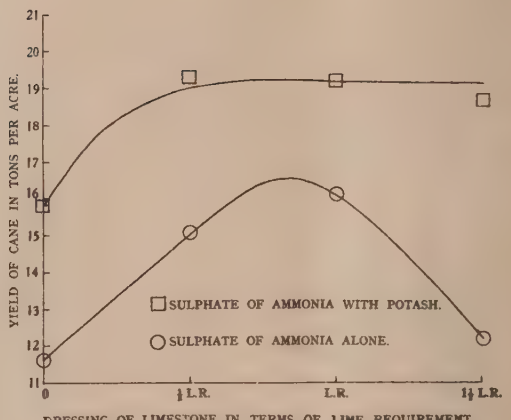

FIG. VII.—EFFECT OF INCREASING DRESSINGS OF LIME ON YIELD IN THE PRESENCE OF SULPHATE OF AMMONIA ALONE AND OF SULPHATE OF AMMONIA WITH POTASH.

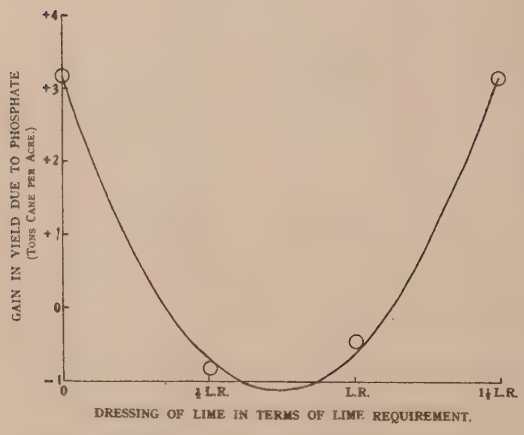

FIG. IX.—EFFECT OF SIZE OF DRESSING OF LIME ON GAIN IN YIELD DUE TO PHOSPHATE.

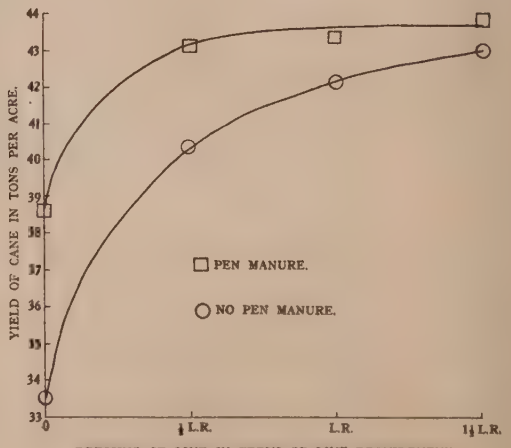

FIG. X.—EFFECT OF INCREASING DRESSINGS OF LIME ON YIELD IN THE PRESENCE AND ABSENCE OF PEN MANURE.

The difference between the effect on yield of the single and double doses of phosphate, at the various dressings of lime, is not statistically significant, *i.e.*, the gains derived from 20 lb. of P_2O_5 and 40 lb. of P_2O_5 to the acre may be regarded as identical for practical purposes. A dressing of superphosphate of about one or two cwts. to the acre would therefore seem adequate to secure maximum results under the conditions which obtain.

It has previously been shown that the effect of phosphate on the gain in yield due to lime is dependent on the size of dressing of nitrogen (Table VII). According to the data summarised in Table XV the effect of phosphate can also be dependent on the size of dressing of lime. In the presence of basal nitrogen and potash it appears that phosphate leads to gains in yield on the more acid soils and on the more heavily limed soils, rather than on soils of intermediate lime status.

This conclusion is in agreement with general theory. It is probable that phosphate is largely present in the form of basic iron and aluminium salts in the more acid soils, and in the form of basic calcium salts in calcareous soils. The natural store of phosphate in both types of soil is therefore likely to be comparatively unavailable. In consequence both types of soil are likely to respond to treatment with water-soluble phosphate, for a common reason.

There are recorded in Table XVIII yield data for experiments with phosphate on an acid red-weathering clay of pH value 5.2 and on a calcareous marl, *i.e.*, two soils at the extremes of the range of lime status. Although these two soil types differ fundamentally from the degenerated loam of Experiment V, the yield data are in complete accord with the general principle which has been established.

TABLE XVIII.—*Gain in yield due to phosphate on an acid clay and on a calcareous marl.*

Yield of Plant Canes (1930-32).

EXPERIMENT.	VIII.	IX.
Soil Type.	Acid red-weathering clay.	Calcareous marl.
Cane Variety.	Uba.	B.H. 10(12).
630 lb. P_2O_5 per acre..	31.84	38.95
No. P_2O_5	29.01	33.81
Gain due to P_2O_5 ..	2.83	5.14

There were 16 replicates of each manurial treatment in Experiment VIII and in Experiment IX. Both experiments were laid down in the form of Latin squares.

On the very acid soil the gain in yield of 2.83 tons of cane is on the borderline of significance. On the calcareous soil the gain in yield of 5.14 tons might be due to chance less than once in 100 times.

THE DEPRESSION OF YIELD BY PHOSPHATE.

Under certain conditions, treatment with phosphate can lead to a significant depression in yield of plant canes. Evidence to this effect has been obtained in Experiment III (Table V). Additional evidence obtained in Experiment X is recorded in Table XIX.

TABLE XIX.—*Depression in yield of plant canes due to phosphate.*

(*Experiment X*).

Soil type.—River alluvium.

Variety of cane.—B.H. 10 (12).

Dressing per acre of superphosphate.	Yield of cane (tons per acre).
Nil	25.15
450 lb. P_2O_5	22.65
Loss due to P_2O_5 ..	2.50

Experiment X was laid down in the form of Latin squares with 12 replicates of each treatment. The phosphate was added in water-soluble form as superphosphate. The loss in yield due to treatment with phosphate in this experiment might be due to chance less than once in 20 times.

The precise nature of the conditions under which dressings of phosphate lead to a depression in yield are under investigation. The data summarised in Table XVII suggest that a depression would be most likely to occur on soils of intermediate lime status, *i.e.*, on soils which correspond to the region lying between half the lime requirement and the lime requirement of the degenerated loam on which Experiment V is laid down (Figure IX). The conditions which determine maximum solubility of phosphate are probably at their optimum in the zone of intermediate lime status. Within this zone, therefore, any adverse effects on yield of phosphate, if this nutrient is present in undesirable excess, are likely to be most clearly evident.

The evidence which has been accumulated suggests that a depression in yield due to phosphate may take place only when a heavy dressing is used. The maximum dressing of phosphate applied in Experiment V is 40 lb. P_2O_5 to the acre. Any apparent depression in actual yield in this experiment is statistically not significant. The dressing of phosphate in Experiment III is 150 lb. P_2O_5 to the acre. On the unlimed plots this dressing led to a significant reduction in yield of 3.23 tons of cane (Table V). In Experiment X treatment with 450 lb. of P_2O_5 to the acre led to a significant loss in yield of 2.50 tons of cane (Table XIX). It is noteworthy however that dressings as large as 630 lb. P_2O_5 to the acre can have a beneficial effect on yield on very acid and on calcareous soils (Table XVIII).

Under certain circumstances excess phosphate can lead to restricted development of the root system and general stunted growth of the plant. Associated with these effects is a characteristic rust of the leaves. A description of these symptoms of phosphate poisoning, and of the conditions under which they can appear, will be given in a later paper of this series.

The Interaction of Phosphate with Pen Manure.

The average gains in yield due to the dressing of pen manure, in the presence and absence of phosphate, which are recorded in Table XVII, are 2.80 and 3.12 tons of plant canes, respectively. Statistically, the difference of 0.32 tons is definitely not significant. *Only a very small proportion of the gain in yield due to the pen manure can therefore be attributed to the phosphate it contains.*

In Experiment V dressings of phosphate averaging 30 lb. of water-soluble P_2O_5 in the absence of pen manure lead to significant gains in yield of 3.48 tons of plant canes on the unlimed plots, and of 2.13 tons on the most heavily limed plots (Table XVII). No such gains are recorded at these extremes of lime status on the plots with pen manure and without inorganic phosphate. Gains of this order, however, appear if small dressings of phosphate are added with the pen manure.

The pen manure applied to Experiment V in 1933 contained 0.19 per cent. of P_2O_5. The amount of phosphate in the dressing of 20 tons of pen manure is therefore 85 lb. of P_2O_5. It appears that the phosphate differs from the potash in the pen manure in that only a very small fraction of the phosphate is available to the plant canes. Alternatively, the phosphate may have become available too late in the life of this crop to be used to maximum advantage.

Interactions of Lime with Pen Manure.

The effect of increasing dressings of lime in the presence and absence of pen manure has been measured in two main experiments, Experiment IV laid down on a red-weathering clay soil, and Experiment V laid down on the degenerated loam. Yield data obtained are recorded in Tables XX, XXI and XXII.

Table XX.—*Effect of size of dressing of lime on yield in the presence and absence of pen manure. (The interaction of lime with pen manure).*

(Experiment IV).

Soil Type.—Red-weathering clay.

Variety of cane.—B.H. 10(12).

Yield of Plant Canes (1929-31) in tons per acre.

Basal dressing (all plots).	Nil.			
Dressing of limestone in 1929.	Nil.	½ L.R.	L.R.	1½L.R.
20 tons pen manure per acre	38.59	43.09	43.36	43.89
No pen manure ..	33.47	40.39	42.18	42.99
Gain due to pen manure	5.12	2.70	1.18	0.90

Gains in Yield due to Limestone.

Limestone in 1929.	½ L.R.	L.R.	1½L.R.	Average.
Pen manure ..	4.50	4.77	5.40	4.89
No pen manure ..	6.92	8.71	9.52	8.38
Diff. in gain in yield due to lime ..	2.42	3.94	4.12	3.49

Experiment IV was laid down on the red-weathering clay soil in 1929. Details for this soil type have previously been given (1). The layout is in the form of three 8 x 8 Latin squares. There are therefore 24 replicates of each treatment. The lime requirement of the soil is 20 tons of ground limestone to the acre.

No basal dressing of inorganic manures was given to the crop of plant canes which was reaped in 1931. The data summarised in Table XX therefore give a straightforward measure of the interaction of lime with pen manure.

The average gains in yield of the plant canes due to limestone and pen manure are 6.62 and 2.47 tons to the acre, respectively. Both gains might be due to chance less than once in 100 times.

The gain in yield due to pen manure in the absence of ground limestone is 5.12 tons of cane to the acre. As the dressing of limestone increases the gain in yield due to pen manure falls continuously and significantly. At the dressing of one-and-a-half times the lime requirement the gain due to pen manure has fallen to the low value of 0.90 tons of cane.

In the presence of pen manure the gain in yield due to limestone increases from 4.50 tons of cane at the half lime requirement to 5.40 tons at the maximum dressing of lime. The average gain is 4.89 tons of cane. In the absence of pen manure the gain due to limestone increases from 6.92 tons of cane at the half lime requirement to 9.52 tons at the maximum dressing. The average gain is 8.38 tons of cane. The gain in yield due to limestone is therefore considerably reduced in the presence of pen manure. The extent of the reduction is dependent on the size of the dressing of lime. It increases from 2.42 tons at the half lime requirement to 4.12 tons at the maximum dressing of lime. This interaction of lime with pen manure might be due to chance rather less than once in 20 times.

The effect of increasing dressings of lime on yield in the presence and absence of pen manure is graphically expressed in Figure X. Curves of diminishing returns are obtained. In the presence of pen manure the curve approaches a maximum more rapidly than in its absence. Consequently the distance between the two curves, which is a measure of the gain in yield due to pen manure, diminishes as the dressing of lime is increased.

It was originally believed (4) that the interaction of lime with pen manure might be related to the content of exchangeable potash of the soil, in that it could be explained on the assumption that increasing doses of lime render increasing amounts of potash available to the plant through base exchange with the soil. Any effect of the potash in the pen manure could be partly negatived by the potash thus released. The more recent investigations which have been described in this paper provide a possible alternative explanation of the interaction of lime with pen manure.

It has previously been shown that if yield of cane is plotted against size of dressing of nitrogen, in the presence and absence of lime, curves of

diminishing returns are obtained which approach each other as the dressing of nitrogen increases. These curves are recorded in Figure II. They bear a very close resemblance to the curves in Figure X, *i.e.*, the interaction of lime with increasing dressings of nitrogen appears to be similar in kind to the interaction of pen manure with increasing dressings of lime.

The increase in yield due to pen manure is known primarily to be due to the nitrogen which it contains. The interaction of lime with pen manure may therefore be an interaction with nitrogen of the pen manure. Under the conditions which obtain in Experiment III, it has been shown that the depressing effect of lime on the gain in yield due to nitrogen, and of nitrogen on the gain in yield due to lime, may be counteracted by the presence of readily available phosphate, but not by potash unless in the presence of adequate phosphate. Trinidad pen manure contains phosphate, but the phosphate appears to exist in an unavailable and therefore inactive form. (*See* opposite page.)

In these circumstances a dressing of available phosphate should remove the depressing effect of lime on the gain in yield due to pen manure. In addition, on a potash-deficient area, the phosphate should enable the potash in pen manure to exert a beneficial effect on the gain in yield due to lime. These hypotheses are under investigation. Preliminary information obtained on the potash-deficient soil of Experiment V is summarised in Table XXI.

TABLE XXI.—*Effect of a basal dressing of phosphate on the interaction of lime with pen manure.*

Yield of Plant Canes (1933-35) *in tons per acre.*

Basal dressing (all plots).	125 lb. N. and 20 lb. water-soluble P_2O_5.			
Limestone in 1929.	Nil.	½ L.R.	L.R.	1½ L.R
20 tons pen manure in 1933	25.88	20.20	29.53	27.38
No pen manure ..	23.30	23.25	24.98	24.09
Gain due to pen manure in presence of P_2O_5	2.58	5.05	4.55	3.29

Gains in Yield due to Limestone.

Limestone in 1929.	½ L.R.	L.R.	1½ L.R	Av.
Pen manure ..	3.32	3.65	1.50	2.82
No pen manure ..	−0.05	1.68	0.79	0.81

In this experiment the gain in yield due to pen manure in the presence of water-soluble phosphate is somewhat irregular. As the dressing of lime increases, however, there is no indication of a serious diminution in the gain, such as can occur in the absence of readily available phosphate.

The average gain in yield due to lime recorded in Table XXI is larger in the presence of pen manure (2.82 tons of cane) than in the absence of pen manure (0.81 tons of cane). In practically every other experiment of the kind, the gain due to lime has been found to be the larger in the absence of pen manure. This experiment differs from the others, in that water-soluble phosphate was applied to the penmanured plots. It seems possible that in the presence of the added phosphate the gain in yield due to lime on this potash-deficient area has been increased by the potash in the pen manure. This conclusion would be in complete accord with the principles established by Experiment III.

A further set of data which are of interest in connection with the interaction of lime with pen manure are recorded in Table XXII. They relate to an experiment in which all plots were given a basal dressing of a complete inorganic manure. The dressing was not large enough completely to mask the effect of the pen manure on the yield of the plant canes. It contained 20 lb. of water-soluble P_2O_5 and 110 lb. of K_2O.

TABLE XXII.—*The interaction of lime with pen manure in the presence of a basal inorganic manure containing readily available phosphate.*

Yield of Plant Canes (1933-35) *in tons per acre.*

Basal dressing (all plots).	Complete inorganic manure.			
Dressing of limestone.	Nil.	½ L.R.	L.R.	1½ L.R
20 tons pen manure per acre	32.35	33.70	35.95	36.36
No pen manure ..	28.02	28.45	30.59	31.11
Gain due to pen manure	4.33	5.25	5.36	5.25

Gains in Yield due to Limestone.

Limestone in 1929.	½ L.R.	L.R.	1½ L.R	Av.
Pen manure ..	1.35	3.60	4.01	2.99
No pen manure ..	0.43	2.57	3.09	2.03
Diff. in gain in yield due to lime.	0.92	1.03	0.92	0.96

The data set out in Table XXII were obtained from the third Latin square of Experiment V. Under the conditions which obtain, parallel curves of diminishing returns result when yield of cane is plotted against size of dressing of lime in the presence and absence of pen manure, there being a basal dressing of a complete inorganic manure. In these circumstances the gain in yield due to pen manure is independent of the size of dressing of lime, and the gain in yield due to lime is slightly but consistently larger on the penmanured plots than on the unpenmanured plots.

Summary and Conclusions.

There are described in this paper a set of results obtained in the main from two complex manurial experiments laid down on sugar cane in the field and continued over a series of crops. By means of these experiments a number of first and second order interactions of lime with nitrogen, phosphate, potash, and pen manure have been established on a statistical basis.

The following among other conclusions can be drawn from the evidence accumulated.

(1) *The first order interaction of lime with nitrogen.*

Gain in yield due to limestone can be considerably decreased by the presence of sulphate of ammonia. The degree to which the gain in yield is decreased is dependent on the size of dressing of sulphate of ammonia, and is greatest at dressings in excess of 80 to 100 lb. of nitrogen to the acre.

Similarly, *gain in yield* due to sulphate of ammonia can be considerably diminished by the presence of limestone. The degree to which the gain in yield is diminished is dependent on the size of dressing of limestone and is greatest at dressings which exceed the lime requirement of the soil.

Yield of cane is increased by increasing the dressing of limestone to a limiting value, which lies in the region of the lime requirement of the soil. At dressings of limestone in excess of this value, yield remains stationary in the absence of sulphate of ammonia, but can seriously fall if sulphate of ammonia is present.

Yield of cane increases in accordance with the law of diminishing returns by increasing the dressing of sulphate of ammonia to a limiting value. The yield curve approaches a maximum more rapidly in the presence than in the absence of lime. At dressings of suphate of ammonia exceeding the limiting value, yield remains stationary on lime-deficient soils, but can very appreciably fall on over-limed soils and on naturally calcareous soils.

(2) *Second order interactions of lime with nitrogen phosphate and potash.*

The diminution in the beneficial effect of limestone, caused by the presence of sulphate of ammonia, can be counteracted by the addition of readily available phosphate. Similarly the diminution in the beneficial effect of sulphate of ammonia, caused by limestone, can be counteracted by phosphate. In the presence of limestone and high nitrogen a dressing of phosphate appears essential if the gains in yield due to the lime and to the nitrogen are to be maintained unchanged.

The adverse effect of sulphate of ammonia on the gain in yield due to limestone does not appear to be counteracted by potash. Under conditions of potash deficiency, however, the gain in yield due to lime in the presence of nitrogen can be increased by the addition of potash, provided that adequate phosphate is present. In these circumstances a dressing of potash equivalent to 50 lb. K_2O to the acre appears sufficient to ensure full beneficial effect of the lime. This effect of potash on the gain in yield due to lime appears to be greatest when lime is present in excess of the lime requirement.

(3) *Other interactions of lime with phosphate.*

The effect of phosphate on the gain in yield due to lime is dependent on the size of dressing of nitrogen. The effect of phosphate is also dependent on the size of dressing of lime. Dressings of phosphate of the order of 20 lb. of water-soluble P_2O_5 to the acre can lead to significant gains in yields on the more acid soils and on the more heavily limed soils, in the presence of basal potash and high nitrogen. Under identical basal conditions, but on soils of intermediate lime status, phosphate can fail to cause an increase in yield.

In certain circumstances, heavy dressings of readily available phosphate can lead to a significant depression in actual yield.

(4) *The interaction of lime with pen manure.*

Evidence is provided to the effect that potash but not the phosphate, in Trinidad pen manure is available to the plant cane crop to which this manure is applied.

The gain in yield due to pen manure and to limestone can be considerably reduced by the presence of limestone and of pen manure, respectively. The degree to which the gains in yield are diminished is dependent on the size of dressing of limestone. These diminutions in gain in yield appear to be due to interaction of the lime with nitrogen of the pen manure. They can be counteracted by a small dressing of readily available phosphate, as in the case of the interaction of lime with inorganic nitrogen.

Importance of the Experimental Data in Relation to Manurial Policy in Trinidad and Antigua.

The experimental data which are recorded in this paper, and the conclusions to which they give rise, are of immediate practical importance to the sugar plantations of Trinidad and Antigua.

Trinidad.

General Manurial Policy.

The imports of sulphate of ammonia into Trinidad in 1928 amounted to 600 tons. In 1934 the imports of this manure had arisen to over 5,100 tons, an increase larger than 700 per cent. It is now customary to apply to plant canes quantities of sulphate of ammonia equivalent to 120 lb. of nitrogen to the acre.

In 1928 ground limestone was applied to only a very small proportion of the sugar-cane soils of Trinidad. The majority of the sugar plantations now have in operation a routine liming programme, in which dressings of ground limestone are given to all acid soils before each replanting with sugar cane, as far as financial considerations permit. More than one dressing of limestone has been applied to certain areas. Some of these areas have become alkaline in reaction and contain free calcium carbonate.

At present it is the exception, rather than the rule, to give dressings of phosphate to sugar cane in Trinidad.

As the quantity of sulphate of ammonia in general use on plant canes exceeds 80 to 100 lb. of nitrogen to the acre, the adverse effect of nitrogen on the gain in yield due to lime, and of lime on the gain in yield due to nitrogen, becomes

TABLE XXIII.—*Effect of excess calcium carbonate on gain in yield due to sulphate of ammonia.*
Soil Type.—Calcareous marl.
Variety of cane.—B.H.10(12), ratoons.

Experiment.	XI (1928-29).				XII (1928-29).		XIII (1934-35).			
Dressing of S/A per acre.	Deep Soil.		Shallow Soil.		Shallow Soil.		Deep Soil.		Shallow Soil.	
	Yield.	Gain.	Yield.	Gain.	Yield.	Gain.	Yield.	Gain.	Yield.	Gain.
Nil	28.51	—	28.03	—	16.38	—	21.10	—	17.13	—
30 lb. N. ..	34.62	6.11	30.65	2.62	17.30	0.92	24.50	3.40	14.50	−2.63
60 lb. N. ..	34.81	6.30	30.26	2.23	17.45	1.07	27.40	6.30	19.69	+2.56
90 lb. N. ..	37.10	8.59	30.56	2.53	17.39	1.01	29.40	8.30	19.69	+2.56

of importance in general field practice. In such case, the gains in yield which are being obtained from the dressings of limestone and sulphate of ammonia may be unnecessarily small. It seems advisable, therefore, to apply a light dressing of readily available phosphate to plant canes on limed soils, to make possible maximum beneficial results from the limestone and sulphate of ammonia.

General manurial policy with respect to potash, in relation to the results obtained from field experiments, will be discussed in a later paper of this series.

Special Manurial Policy on Calcareous Soils.

Sugar cane is extensively grown on a calcareous soil type in Trinidad. This soil type possesses a marl subsoil which frequently approaches to within a few inches of the surface. Under such conditions, dressings of sulphate of ammonia give abnormally small increments in yield. The results obtained in Experiments XI, XII and XIII (Table XXIII) are to be regarded as typical.

The layout of each of these three experiments was in the form of four contiguous 4 x 4 Latin squares. One of the four squares in Experiment XI and in Experiment XIII, covered a patch of soil of shallow depth. In Experiment XII all four squares were laid down on shallow soil.

The gain in yield due to a dressing of 90 lb. of nitrogen on this calcareous soil type exceeds 8.5 tons of cane where the topsoil is deep. The maximum gain due to this dressing of nitrogen is 2.6 tons of cane where the marl subsoil approaches the surface.

The conditions which obtain on the patches of shallow soil are similar to, but more extreme than, those recorded in Table XIII for the plots of Experiment V which were dressed with one-and-a-half times the lime requirement of the soil. In Table XIII it is shown that the gain in yield due to a dressing of 70 lb. of nitrogen to the acre can fall from eight tons to four tons of cane as the treatment with lime is increased from 16 tons to 24 tons of ground limestone to the acre.

The shallow patches on the calcareous soil type cover in all an extensive area. The loss in yield due to the comparative failure of sulphate of ammonia on these patches presents a serious economic problem. It seems probable that a dressing of phosphate, supplemented with potash if necessary, would counteract this adverse effect of excessive lime in the soil on the gain in yield to which sulphate of ammonia can give rise.

ANTIGUA.

Sugar cane is grown almost entirely on calcareous soils in Antigua. It will be shown elsewhere that whereas organic manures can give rise to significant gains in yield on these soils, sulphate of ammonia can fail to give increases in yield. For this reason organic manures have been attributed with special properties, and the use of inorganic manures has been decried.

The organic manures which have been successfully used contain phosphate. In some of them phosphate is present in water-soluble form in large quantity. The experimental data which are recorded in this paper make it probable that the phosphate in the organic manures enables the nitrogen which is present to exert its normal beneficial effect, and that successful use could be made of inorganic nitrogenous manures provided that dressings of readily available phosphate are also applied.

Acknowledgments.

The author wishes to acknowledge his indebtedness to Waterloo, Caroni and Ste. Madeleine Estates for their assistance and co-operation in the experiments described, and to Imperial Chemical Industries, Ltd., for the financial assistance which has made it possible to carry out Experiment III.

Part of the data set out in Tables XIII, XIV and XX have previously been published in the *Empire Journal of Experimental Agriculture* (3, 4).

REFERENCES.

(1) Turner, P. E. (1935). Recent investigations on sugar cane and sugar-cane soils in Trinidad, I, *Tropical Agriculture*, XII, 10, p. 262.

(2) Turner, P. E. (1935). Effect of manurial treatment on growth of sugar cane. *Tropical Agriculture*, XII, 7, p. 179.

(3) Turner, P. E. (1934). Recent investigations on sugar cane and sugar-cane soils, I. *Empire Journal of Experimental Agriculture*, II, 5, p. 78.

(4) Turner, P. E. (1934). Recent investigations on sugar cane and sugar-cane soils, II. *Empire Journal of Experimental Agriculture*, II, 6, p. 103.

(5) Williams, C. H. B., and Follett-Smith, R. R. (1933). Field experiments with sugar cane. *Department of Agriculture, British Guiana, Sugar Bulletin No. 1.*

(6) Turner, P. E. (1930). The state of unsaturation of the soil in relation to its field behaviour and lime requirement. *Soil Science*, XXX, 349.

Appendix II.

ANALYSIS OF VARIANCE OF AN 8 × 8 LATIN SQUARE WITH THREE STRIP TREATMENTS.

(The yield data for the individual plots of the square are recorded in Figure VIII).

Main Treatments.

Due to	D.F.	Sum of Squares.	Mean Square.	$\frac{1}{2}\log_e$.	Diff. in $\frac{1}{2}\log_e$.
Rows	7	94,174.75	—	—	—
Columns	7	7,396.75	—	—	—
Treatments	(7)				
Lime	3	297.50	99.17	—	—
Pen Manure	1	8,556.25	8,556.25	2.2246	1.2219*
Lime × Pen Manure ..	3	2,102.75	700.92	—	—
Error	42	31,203.00	742.93	1.0027	—

Strip Treatments.

Rows	7	94,174.75	13,453.54	—	—
Strip treatments	(2)				
$P_0 v P_1+P_2$	1	1,485.12	1,485.12	1.3491	0.8630†
$P_1 v P_2$	1	1.50	1.50	—	—
Rows × Strip treatments ..	14	3,701.38	264.38	0.4861	—

Interaction of Strip Treatments with Main Treatments.

Strip treatments × main treatments ..	(14)				
P × Pen manure	2	398.38	199.19	—	—
P × Lime	6	5,203.00	867.17	1.0801	0.6418*
P × Pen manure × Lime	6	2,239.75	373.29	—	—
Strip treatments × main treatments × rows	98	23,544.88	240.25	0.4383	—

Sub-analysis of Strip Treatments × Lime.

P × [(O + 1½ L.R.) *v* (½ L.R. + L.R.)] ..	2	3,375.37	1,687.69	1.4130	0.9747*
P × (O *v* 1½ L.R.)	2	1,469.32	734.91	0.9973	0.5590
P × (½ L.R. *v* L.R.)	2	357.81	178.91	—	—

TABLE OF SIGNIFICANCE.

n_1.	n_2.	P = 0.01.	P = 0.05.
1	14	1.0909	0.7630
1	45	0.9950	0.7037
2	60	0.8025	0.5738
6	60	0.5687	0.4064

* Due to chance less than once in 100 times. † Due to chance less than once in 20 times.

A SIMPLE EXPLANATION OF THE TECHNOLOGICAL TERMS USED TO EXPRESS THE RESULTS OF SUGAR-CANE EXPERIMENTS.

By J. G. Davies,
Department of Sugar Technology, Imperial College of Tropical Agriculture, Trinidad.

I.—Introduction.

The introduction of chemical control into sugar factories has led to the evolution of technique and formulae whereby an accurate estimate can be made of yields and losses. Similar treatment is applied to the results of analyses of maturity and experimental samples, in order that the conclusion of the laboratory can be set out in more definite terms. As far as the field manager or overseer is concerned, such results take the form of a figure expressing "Tons 96° Sugar per acre" for each field or plot. Such figures can be compared one with another only as long as the method of calculation is the same in all cases, and provided this is so, variety trials carried out on different estates can be assessed by a member of the field staff merely by inspection. Usually, however, each factory laboratory uses a different method of calculation, which is based on the equipment available and the observed average results of the factory work as obtained from the control sheet. This article attempts to define the technical terms and to describe the methods of calculation used so that the non-technical reader can better appreciate the derivation of the laboratory figures.

II.—Analytical Terms.

An analysis sheet comprises a series of columns, each of which is meant to convey certain definite information. A typical series of column heads, together with their explanation, is as follows :—

(*a*) *°Brix.*—The Degree Brix is indicative of the density of the juice, the higher the figure, the greater the density. It is named after the person who invented the instrument whereby the density is determined. Expressed in simple terms, *°Brix is the grams or lb. of solids in* 100 *grams or lb. of juice*, solids being taken to mean everything in the juice except water and suspended material. During the period of ripening, for example, when water in the cane is being lost by evaporation and the canes are drying and loosing the green colour, the °Brix of the juice rises fairly rapidly.

(*b*) *%Sucrose.*—This needs but little explanation. Obviously the sucrose must be included amongst the other solids when they are expressed as °Brix, but since the sucrose is the most important constituent of the juice, it is determined separately. Any other constituent could be so determined if circumstances warrant it, and on special analyses sheets such terms as "%Reducing Sugars" or "%Ash" may appear. The polariscope is used to determine the amount of sucrose in the juice, and the answer is again expressed as *grams or lb. of sucrose in* 100 *grams or lb. of juice*. In any impure juice, therefore, this figure must be less than the °Brix.

(*c*) *Purity.*—After the above two figures have been determined by analysis, a simple calculation is made to determine the Purity. The formula is :—

$$\text{Purity} = \frac{\%\text{Sucrose}}{\text{°Brix}} \times 100 \quad .. \quad .. \quad .. \quad (1).$$

In other words, the *Purity expresses the sucrose as a percentage of the solids*, and hence the amount of water and suspended matter is left out of consideration.

These explanations refer specifically to a Juice Analysis. %Sucrose in Bagasse (or Megass) is obtained in much the same way as for juice and the answer is expressed in the same way. Bagasse analysis is not always carried out as it is not absolutely necessary in order to obtain an estimate of the Sucrose % Cane. This latter estimate can be obtained in various ways, and it is the first step necessary for the Commercial Sugar calculation.

III.—Method of Calculation.

(A) From Crusher Juice Analysis.

Method (A).—The Crusher Juice is the juice expressed by the first unit of the factory mill. In a normal tandem of mills, the analysis of this juice bears a working relationship to the analysis of the whole juice in the cane. This statement needs elaboration. The juice as it exists in the cane is known technically as the *Normal Juice*. The cane itself can be divided into the soft pith, which contains a pure juice, and the hard rind which contains a relatively impure juice. Most of the juice expressed by the crusher comes from the pith, and on analysis, is therefore found to be of higher purity than the Normal Juice. Depending on the severity of the milling, a working relationship can be struck between the analysis of the Crusher Juice and that of the Normal Juice. Hence, once this relationship has been found for any given mill, the analysis of the Normal Juice can be calculated from the obtained analysis of the Crusher Juice. For example, let us suppose that a Crusher Juice analysis is as follows :—

°Brix .. . 19·25
%Sucrose .. 16·68
Purity $= \frac{16{\cdot}68}{19{\cdot}25} \times 100 = 86{\cdot}7$ (Applying formula (1)).

And that the relationship between Normal Juice and Crusher Juice analysis is as follows :—

Normal Juice °Brix = Crusher Juice °Brix × 0·975 (N. J. Factor).
Normal Juice Purity = Crusher Juice Purity − 2·50 (Pur. correction).

(The N. J. Factor (0.975) and Purity Correction (-2.50) are obtained by simple calculation from the analyses of the Crusher Juice and the Normal Juice in the routine Laboratory. They may change with change in milling conditions &c.) then :

Normal Juice Brix $= 19{\cdot}25 \times 0{\cdot}975 = 18{\cdot}76$.
Normal Juice Purity $= 86{\cdot}7 - 2{\cdot}50 = 84{\cdot}2$

$$\text{Normal Juice Sucrose} = \frac{18{\cdot}76 \times 84{\cdot}2}{100} = 15{\cdot}79 \text{ (Using formula (1))}.$$

These answers provide a reasonably accurate analysis of the Normal Juice without involving the factory in the expense and time lost in giving a separate milling test to each sample. This calculated analysis is the basis of the future calculations in this method.

The next term to be considered is *Normal Juice % Cane* (or *% Crushing*). This figure expresses *the weight of Normal Juice as a percentage of the weight of cane from which it was extracted by the mills*. Hence the figure 78.2 means that 78.2 tons of Normal Juice were expressed by the mills from every 100 tons cane crushed. (In actual practice, maceration water is added during milling and the juice obtained is called "Mixed Juice" *i.e.*, Normal Juice plus Maceration Water. The obtaining of the weight of Normal Juice requires more technical considerations, but it must be taken for granted that the weight of Normal Juice can be determined.) Sucrose in juice leaving the mills and entering clarification can now be calculated as follows :—

$$\text{Sucrose in Juice \% Cane} = \frac{\text{N.J. \% Cane} \times \text{Suc. \% N.J.}}{100} \quad \ldots (2).$$

Applying this to the above example :

$$\text{Sucrose in Juice \% Cane} = \frac{78{\cdot}2 \times 15{\cdot}79}{100} = 12{\cdot}35.$$

This is also known as the "*Indicated Sucrose % Cane*" and means *the tons of sucrose which the mills have expressed in the juice from* 100 *tons cane*. The rest of the sucrose which came into the factory in the cane has not been expressed and has been sent away in the bagasse, and is therefore of no further concern in this Method. In the factory, this *sucrose* would pass into the boiling house for clarification and boiling, &c., and *would finally emerge either as sugar in the bag or as sugar in Final Molasses*. It is therefore necessary to calculate the proportion of sucrose which will be in the sugar in the bag and that which will be in the Final Molasses. The controlling factor is the *Purity* of the Normal Juice. Two formulae are available one of which, known as Deerr's S-J-M formula, requires more elaborate analysis and is seldom used in the British West Indies. The other, known as Winter's formula, is as follows :—

$$\text{Winter's Factor} = 1{\cdot}4 - \frac{40}{\text{Purity of N.J.}} \quad \ldots (3).$$

The answer to this calculation gives the proportion of the sucrose in the juice which is expected to be found in the sugar in the bag, and it is known as Winter's factor. Winter's factor for the example quoted above is :—

$$1{\cdot}4 - \frac{40}{84{\cdot}2} \text{ (Using formula (3))}.$$
$$= 1{\cdot}4 - {\cdot}475$$
$$= 0{\cdot}925$$

Therefore the actual percentage of sugar which is expected in the bag is :—

$$\text{Sucrose in juice \% cane} \times \text{Winter's factor} = 12{\cdot}35 \times 0{\cdot}925.$$
$$= 11{\cdot}43\%.$$

This is known as *Available Sucrose.*

∴ Available Sucrose in juice % cane = 11.43.

All factories do not recover exactly the amount which has been calculated in this way, some obtain higher and others lower results. An adjustment may therefore be made which is known as the Boiling House Efficiency (or B.H.E.); this is derived from the chemist's calculations of the factory work, week in and week out. Assume the factory under consideration to have a B.H.E. of 98.5 per cent., the necessary adjustment is :

$$\text{Available Sucrose in juice \% cane} \times \text{B.H.E.} = \frac{11{\cdot}43 \times 98{\cdot}5}{100}$$
$$= 11{\cdot}26\%$$

It must be remembered that this figure is *sucrose* not *commercial sugar*. The "standard" commercial sugar is one which contains 96 % sucrose or, to put it in another way, polarises 96°. Therefore to *change the Available Sucrose into Available* 96° *Sugar*, it is only necessary to divide by $\frac{96}{100} = .96$.

$$\text{Avail. 96° Sugar in juice \% cane} = \frac{\text{Avail. Suc. in juice \% cane}}{0{\cdot}96} \quad \ldots (4)$$
$$= \frac{11{\cdot}26}{{\cdot}96}$$
$$= 11{\cdot}73$$

This is expressed simply as 96° *Sugar % Cane.*

The field returns are then consulted for the yield of the particular field or plot from which this sample was obtained. Assume this to be 27.2 tons of cane per acre. Since all the above calculations are on a weight and percentage basis, then—

$$\text{Tons 96° Sugar per acre} = \text{Tons cane per acre} \times \text{96° Sug. \% Cane} \ldots (5).$$
$$= \frac{27{\cdot}2 \times 11{\cdot}73}{100}$$
$$= 3.19$$

To obtain "Tons of Cane per ton of Sugar" requires but a further simple calculation :—

96° Sugar % Cane = 11·73 (from formula (4)).
i.e., 100 Tons Cane yield 11.73 Tons Sugar.
∴ 1 Ton Sugar is derived from $\frac{100}{11{\cdot}73} = 8{\cdot}53$ Tons of Cane.

Method (*B*).—Another and more rapid method may be used. Just as the analysis of the Crusher Juice bears a relationship to the analysis of the Normal Juice, so also does it bear a relationship to the analysis of the cane itself. A sweet cane must obviously have a sweet juice. Over a reasonably long period, and assuming that the analyses of both the Crusher Juice and the Cane itself is obtained, a ratio can be worked out between the Sucrose % Crusher Juice and the Sucrose % Cane. This is known as the *Java Ratio* and is expressed as :—

$$\text{Java Ratio} = \frac{\text{Sucrose \% Cane}}{\text{Sucrose \% Crusher juice}} \quad (6)$$

Strictly speaking, this figure holds good only for the particular set of conditions of cane and milling at the time of analysis, but it can be extended in its use to be applied to other and similar conditions. For example, it may be assumed that in any one factory, the Java Ratio is approximately constant under any particular set of seasonal conditions, and it may, therefore, vary not only from factory to factory but also within any one factory. In the example used in Method (A), assume that the Java Ratio has been determined and found to be 0.785. The analysis of the Crusher Juice is as before, namely :—

Brix	....	....	19·25
%Sucrose	....	....	16·68
Purity	....	....	86·7

(And the analysis of the Normal Juice can be obtained by the same series of calculations). Apply the Java Ratio according to formula (**6**), then :—

$$0{\cdot}785 = \frac{\text{Sucrose \% Cane}}{16{\cdot}68.}$$

$$\text{Sucrose \% Cane} = 16{\cdot}68 \times 0{\cdot}785$$

$$= 13{\cdot}09$$

It must not be confused with Sucrose in Juice % Cane obtained by formula (**2**). *This figure, 13.09 per cent., is an estimate of the total sucrose in the cane, not in juice only.* It is therefore necessary to know what proportion of the sucrose in the cane will be expressed in the juice and what will be discarded with the bagasse. This statement also needs elaboration. Every 1,000 tons of cane which is ground by the mills contains, according to the answer of the last calculation, 130.9 tons of sucrose. During the milling process, most of this sucrose will be expressed in the juice and the remainder remains in the bagasse. The proportion which is expressed in the juice is known as the "*Mill Extraction*" or "*Sucrose Extraction*" and depends on the efficiency of the design and operation of the mill. It is calculated every 24 hours by the Chemist. Assume, in this case, that the mill extraction is 93.5 per cent., the calculation can be put in the form of a formula :

$$\left.\begin{matrix}\text{Suc. Extraction}\\ \text{Mill Extraction}\\ \text{Suc. expressed in juice}\\ \text{\% Sucrose in cane.}\end{matrix}\right\} = \frac{\text{Tons suc. in Juice}}{\text{Tons suc. in Cane.}} \times 100 \quad (\mathbf{7}).$$

∴ Tons sucrose in juice = Tons sucrose in cane × sucrose extraction. Or, returning to the percentage basis as before :

$$\text{Suc. in juice \% Cane} = \text{Suc. \% cane} \times \text{Suc. extraction}$$

$$= 13{\cdot}09 \times \frac{93{\cdot}5}{100}$$

$$= 12{\cdot}24$$

This is another estimate of the same figure obtained in formula (**2**). It will be noticed that it differs slightly, but not to any appreciable extent.

The procedure is now exactly the same as for Method (A), as follows :—

Winter's factor will be the same, since with an identical purity adjustment, the Normal Juice purity will be as before.

Winter's factor = 0·925 (using formula (**3**)).

∴ Available sucrose in Juice % Cane = 12·24 × 0·925.

= 11·32

Adjusting for the B.H.E. $\frac{11{\cdot}32 \times 98{\cdot}5}{100} =$ 11·15 %

Converting sucrose to 96° Sugar by formula (**4**)

$\frac{11{\cdot}15}{{\cdot}96}$ = 11.62 Available 96° Sugar in juice % Cane.

Tons 96° Sugar per acre from formula (**5**).

$\frac{27{\cdot}2 \times 11{\cdot}62}{100} = 3{\cdot}16$

Tons Cane per Ton of Sugar = $\frac{100}{11{\cdot}62} = 8.60$

Neither the result of the "Tons 96° Sugar per acre" calculation nor of the "Tons Cane per ton of Sugar" calculation differ very much from that obtained by Method (A). In actual practice, the answers may differ more widely, but the essential fact is that the two methods can be used for calculating the same result, starting only with the analysis of the Crusher Juice and the Boiling House Efficiency and either the Java ratio or the % Crushing.

(B) By Complete Analysis.

Method (C).—Complete analysis of the cane can be carried out either by grinding a sample in the hand mill or by grinding the entire truck load, plot yield or field yield in the factory mill at one time. Cane, after milling, is separated into Juice and Bagasse.

Cane = Juice + Bagasse.

Therefore, as explained before, all the sucrose in the cane leaves the mill either in the juice or in the bagasse :—

Suc. in Cane = Suc. in Juice + Suc. in Bagasse (**8**).

By weighing the cane and the juice, the weight of bagasse can be obtained by difference, and by sampling and analysing the juice and the bagasse, the weight of sucrose in each of these products can be calculated. Assume that a highly efficient hand mill is available (a factory mill test will not be considered because of maceration water complications, &c.), and that the following weights have been obtained :—

Weight of cane sample	....	....	....45 lb.
Weight of juice expressed	....	....	....25 lb.
Weight of bagasse (by difference)	....		....20 lb.

Also that the analysis of the juice and bagasse obtained in the Laboratory are as follows :—

Juice	° Brix	=	19·29
	% Sucrose	=	16·80
	Purity	=	87·1
Bagasse	% Sucrose	=	8·45

It is now necessary to calculate the weight in lb. of sucrose in the juice and in the bagasse as follows :—

$$\text{Weight of Suc. in juice} = \frac{\text{wt. of juice} \times \text{suc. \% juice}}{100}$$
$$= \frac{25 \times 16{\cdot}80}{100}$$
$$= 4{\cdot}20 \text{ lb.}$$

Similarly :

$$\text{Wt. of suc. in bagasse} = \frac{\text{wt. of bagasse} \times \text{suc. \% bagasse}}{100}$$
$$= \frac{20 \times 8{\cdot}45}{100}$$
$$= 1{\cdot}69 \text{ lb.}$$

Therefore by formula (**8**)

$$\text{lb. sucrose in cane} = 4.20 + 1.69$$
$$= 5.89 \text{ lb.}$$

This weight of sucrose, 5.89 *lb. is present in the determined weight of cane, namely* 45 *lb.* It is now only necessary to express it as a percentage :

$$\text{Sucrose \% Cane} = \frac{\text{Weight of suc. in cane} \times 100}{\text{Weight of cane}}$$
$$= \frac{5{\cdot}89 \times 100}{45}$$
$$= 13{\cdot}09$$

The result is the same as that obtained by Method (B), using the Java Ratio according to formula (**6**).

The essential data collected so far by this Method are :—

Hand Mill Juice Purity = 87·1
Sucrose % Cane = 13·09.

In order to calculate "96° Sugar % Cane" Formula (**4**) it is first necessary *to adjust the purity of the Hand Mill juice so that it more closely approximates to the purity of the juice which would have been obtained, had the cane been ground in the heavier factory mill.* This is in accordance with the previous statement that the higher purity pith juice is expressed before the lower purity rind juice. The latter is only extracted under comparatively high pressures such as exist in a factory milling plant. In Methods (A) and (B), the purity adjustment has taken the form of deducting 2.50 from the purity of the Crusher Juice. Since the hand mill is less efficient than the factory crusher, a slightly bigger deduction must be made to reduce the hand mill juice purity to the standard of the factory mill. The actual magnitude of the deduction is determined by experiment. For the purpose of the present example, assume that the determined correction to be applied is 2.9 in which case the purity of the Normal Juice will be :—

$$\text{Purity of Normal Juice} = \text{Purity of hand mill juice} - 2{\cdot}9$$
$$= 87{\cdot}1 - 2{\cdot}9$$
$$= 84{\cdot}2$$

This is the same as the purity obtained by deducting 2.5 from the purity of the Crusher Juice. (*See* Methods (A) and (B).) The Hand Mill analyses have now been corrected, where necessary, to give results analogous to the figures which would have been obtained had it been convenient and had the sample been big enough to grind in the factory mill. Recapitulating :—

	Obtained Hand Mill Data.	Correction to Hand Mill Data.	Calculated Factory Mill Data.
Juice :			
Brix ..	19.29		
% Sucrose ..	16.80		
Purity ..	87.1	deduct 2.9	84.2
Bagasse			
% Sucrose ..	8.45		
Cane :			
% Sucrose ..	13.09 by calculation	none	13.09

The calculated factory mill data is now used in exactly the same way as in Method (B). The calculations are as follows :

Assume the Mill Extraction (Formula (**7**) to be 93.5 as before. Apply Formula (**7**).

$$\text{Suc. in Juice \% Cane} = \text{Suc. \% Cane} \times \text{Suc. Extraction.}$$
$$= 13{\cdot}09 \times \frac{93{\cdot}5}{100}$$
$$= 12{\cdot}24$$

Then follow Method (B) from that point onwards. The answer will obviously be the same, since the calculations and the figures are the same.

The examples used in the above three methods were established so as to yield the same or approximately the same answer in each case. This was done so that the steps common to two methods could be more easily recognized. It is no guarantee however, that if an actual sample was dealt with by each of the three methods, the results would be as close as those quoted. The reason for this is that each method introduces certain known errors, which, for any one factory, are greater in one method than in another, hence the reason why different methods are used at different factories. The main point to keep in mind is that the answers are *relative*, provided the same procedure and same method is always used. The greatest error is, obviously, the sampling of the cane or juice, and it is essential that this is carried out as carefully as possible with the minimum of deliberate selection. If this is not done, the whole value of the analysis and calculation is nullified.

IV. Summary.

The three commonest methods used to calculate the results of plot or field samples have been explained in non-technical language with the aid of examples. These explanations have been attempted with the view solely to help the field staff to appreciate the derivation of the figures calculated by a factory laboratory. It is hoped that they, in turn, will co-operate with the laboratory in delivering true samples of the cane.

REVIEWS.

SUGAR-CANE CULTIVATION.

Ransomes, Sims & Jefferies Ltd., England.

This is a brochure published on behalf of the well known firm of agricultural implement manufacturers, Messrs. Ransomes, Sims & Jefferies Ltd. of Ipswich. It is intended to show the different types of implements which they are offering for sale as suitable for the cultivation of the sugar-cane crop. The publication is in the nature of a series of illustrations with suitable captions, showing the implements at work in the more important cane producing countries of the tropical world from Puerto Rico to Natal and Fiji. The photography is excellent and indicates to the reader the general conditions for which each type of implement is adapted and also the quality of the work—depth, pulverisation, &c. —when completed. The implements depicted include ploughs, harrows, cultivators and ridgers and range from the light single-furrow mouldboard plough for a two-ox yoke to the multiple disc types for mechanised traction. The latter are, of course, capable of completing large acreages per day and doing thorough cultivation to any depth up to two feet. The pamphlet is of interest to all prospective purchasers of cultural implements and particularly to those concerned with the growing of sugar-cane.

* * *

D. D. P.

INDIVIDUAL HEALTH.

By E. Obermer. *Chapman & Hall*, London, 1935. Vol. I Biochemical Technique, pp. 244, 15*s*.

The author's aim in this book is to describe a system, based on biochemical analysis, whereby the "functional efficiency" of the human subject is gauged, and his degree of "physiological adaptation" to the stresses and strains of living and growing is measured. These objects are extremely ambitious, as the author agrees, but the importance of maintaining the human subject in good health, rather than treating him in sickness, is urged as a sufficient reason for the attempt. Individuals offering themselves for examination are called upon to submit to a complete "adaptional survey", which is two-fold in its object, namely, (1) to detect the earliest signs of lowered resistance to disease, and (2) to raise the standard of health by suitable treatment, based on the quantitative assessment of the efficiency of the various organs of the body. The programme is undoubtedly very idealistic, and the technique very complicated.

In this first volume of some 250 pages are described the precise details of the biochemical tests that the author suggests might be applied in order to gain the necessary information on which the diagnosis is largely based. Evidently a great deal of careful consideration has been given to the selection and modification of the analytical chemical methods, and to the design and equipment of the chemical laboratory. The procedure is planned on "mass production" lines, and with due regard to time and cost. Many of the tests described might be useful to analyst chemists working in Public Health, Animal Physiology, Pharmacology and Agricultural Chemistry.

Without doubt, this book will inspire the greater application of biochemistry in the study of health and disease. A second volume to follow will form a continuation in which further analytical procedures are described, and additional volumes will deal with the interpretation of the biochemical data and the application of the methods to problems of individual health. The suggested system is perhaps the first of its kind to be devised and presented in full practical detail, and its publication marks a new era in medical science. Its serious study is recommended to all of those who are dissatisfied with the somewhat haphazard methods of the past, and who believe more in prevention than in cure.

* * *

F. H.

CHRONICA BOTANICA, Vol. I.

Edited by Fr. Verdoorn, Holland, 1935, pp. 447. Price 15 Dutch florins.

This purports to be an independent annual devoted to all branches of plant science. It is divided into three main sections. The first, prefaced by an article on "International co-operation among botanists" by E. D. Merrill, contains a calendar and notes of interest on the Sixth International Botanical Congress and on other botanical conferences. The second and largest is entirely concerned with work of a botanical nature in progress throughout the world. It includes informative news grouped under countries about institutions, societies and personalities and is liberally illustrated with photographs of individuals, plants, institutions, local scenes, &c. The third section comprises sub-sections devoted to correspondence and advertisements. In it will also be found a list of new periodicals and of new and revised addresses of botanists, and an amusingly instructive illustrated history of botany in the Netherlands. *Chronica Botanica* should prove a handy directory and although this first volume is necessarily incomplete it represents a creditable attempt to compile material which will not only be of value to botanists but also to others interested in plant science.

G. G.

We are much indebted to Messrs. Thomas Murby & Co., 1, Fleet Lane, E.C.4, for presenting us with Volumes I and II of the Transactions of the Third International Congress of Soil Science which was held at Oxford, in August, 1935. Volume I comprises the "Commission Papers" and Volume II the "Plenary session papers and the Presidential address". Volume III which is in preparation will consist of "Further contributions to the Subjects discussed in Volume I and other matter". Volume I is priced at 23*s*. net to members of the International Society of Soil Science and at 28*s*. to non-members, Volume II at 11*s*. and 13*s*. respectively.

CHEMICAL NOTES.

Compiled by the College Department of Chemistry and Soil Science.

The Use of Rubber Plates in Printing.

A process for printing from rubber plates has been developed at Akron, by the B. F. Goodrich Company, which may alter traditional methods of printing. Printing from rubber type is not new. Every one is familiar with the "rubber stamp," which has long been used to stamp out short notices or designs. Until recently, however, rubber as a substitute for metal in jobs requiring thousands of copies was thought to be impractical.

The new "elastotypes", or rubber plates overcome many of the former objections to rubber as a printing material, and have several advantages over ordinary metal in certain types of work. They are particularly well adapted to printing on fragile or brittle materials such as tissue paper, cellophane, celluloid, wood, metal, fibre and glass, which might be injured by metal type. Bond and other hard-surfaced papers print better from rubber because it conforms to the irregularities of the paper and is less affected by pressure change. Tests indicate that because rubber spreads a thinner film of ink than metal the saving of ink runs as high as 30 to 40 per cent. For the same reason, printing from rubber dries more quickly. Rubber on the other hand, swells when oil inks are used, and certain special inks are required to reduce the swelling to a minimum. As yet, half-tones, except very coarse screen, cannot be printed successfully in long press runs.

It is in the field of book printing that rubber plates offer the greatest promise for the present. Books have never been printed from the speedy rotary presses such as large newspapers have. They are usually run off on flat bed presses. As rubber plates can be curved without distorting the type faces, they may make book printing on rotary presses practical. Scribner's Press recently printed the first book from rubber plates in the United States, "The Emerald Murder Trap."—(*Science*, Vol. LXXXII, No. 2119, *Supp.*, p. 9, 1935.)

* * *

A New Process for the Manufacture of Soap.

The chief drawback of the present soap-boiling processes is that they are not continuous, and lengthy operations are subsequently required before the soap can be marketed. A new process which solves some of these difficulties has been patented by C. M. Adcock and is based on the fundamental principle that in organic chemistry where ionic reactions are not involved, the rate of reaction is a function of the temperature. In general a rise of 10°C. doubles the rate of reaction.

Theoretically, very rapid saponification takes place at 250 to 300°C., but soap normally decomposes at this temperature. By keeping the reaction time very short (30 seconds) and working at high pressures (800 to 1,500 lb. per square inch) the soap formed is found to be very stable. The process can be made continuous by carrying out the reaction in a tube of small diameter—$\frac{1}{8}$th inch bore was found satisfactory, and a high boiling point hydro-carbon oil formed a suitable heating medium. In one experiment two kilograms of cottonseed oil were mixed with 800 grams of caustic solution, and the whole was saponified by pumping through the reaction tube immersed in an oil bath at about 300°C. The time of transit was about 30 seconds, giving a velocity of approximately eight feet per second. If hydrated soap was required, the saponified mixture was passed through either an air cooled or water cooled coil before discharging into a spraying chamber. The glycerine produced from the soap reaction was either retained in the soap or vaporised in the steam, depending on the cooling temperature. It was found in practice that the glycerine content of the soap could be reduced to about two per cent.

An interesting point is that dyes in many oils were bleached during the saponification process, and hence the soap powders produced were always of a better colour than would be expected of the original oils. Palm oil was especially noticeable in this respect. A certain amount of deodorising also took place so that soaps could be made from inferior oils.—(*Ind. Chemist*, May 1935, p. 181.)

* * *

Carob Flour as a Foodstuff.

In parts 1 to 5 of Vol. LXVIII (1935) of the *Rendiconti of the Reale Instituto Lombardo di Scienze e Lettere*, Prof. Adriano Valenti, of the University of Milan, gives the results of experiments in which rats and dogs were fed with carob germ flour, either raw or roasted, and in some cases boiled with water. The flour, prepared by grinding finely the germs of the carob seeds, has a sweetish taste and adheres to the palate like a gummy material. Its percentage composition was found to be: water, 8.95; proteins, 55.30; fats, 5.21; lecithin, 1.34; ash, 6.70; cellulose, 2.32; carbohydrates, 20.18. It thus appears to be richer in protein than any other food of vegetable origin. The biological experiments show nevertheless, that it is tolerated perfectly as a food by animals. With none of the rats (26), was any ill-effect observed, and regular increase in weight occurred, particularly with young, growing animals. The rats compared well with those of a second group fed on a diet of bread and milk. Similar results were obtained with two dogs, one of which was fed, first on bread and water, then on the carob flour, and later on bread and water again; with the other dog, part of the bread in the initial and final stages was replaced by horseflesh.—(*Nature*, Vol. CXXXVI, No. 3431, p. 190, 1935.)

SUGAR NOTES.

Compiled by the College Department of Sugar Technology.

Adsorptive Properties of Synthetic Resins (and their Possible Application to the Purification of Solutions). *B. A. Adams and E. Leighton Holmes.*

Condensation products of polyhydric phenols with formaldehyde varying from voluminous to hard compact materials have pronounced and selective adsorptive properties, and, as some of these products may be prepared at an economic price, their application to the purification of solutions, and to the extraction of dissolved substances is practicable. A note* regarding this interesting discovery has already been published.

Preliminary experiments were made with a tannic acid resin through which a very dilute solution of ferric chloride was passed in tubes. It was found that the resin was coloured blue at the entry of the solution, the coloration extending down the bed as the passage of the iron solution continued. Tests indicated complete absence of iron in the filtrate. On treating the resin with dilute HCL, the colour disappeared as the iron was removed from it. It was calculated that 0.133 grm. of iron had been absorbed by the resin, and analysis showed 0.134 grm. had been recovered.

In another series of experiments, resins set up in tubes (as before) were treated with 5 per cent. sodium chloride solution to obtain saturation with sodium ions. Tap water (London Water Board) of 20 parts per 100,000 hardness was passed through the materials at a rate of about 200 c.c. per hour. Each 100 c.c. of the filtrate was tested for hardness, and when a value of 1° of hardness was obtained the experiment was considered finished. Zero hardness was obtained for the most part, and the softening ended abruptly as with a glauconite and not tending to yield an incompletely softened water over a long period as do synthetic zeolites.

Since the resins remove completely both alkalis and carbonates from solution they may be used for removal of lime in the "excess lime" process of water purification and for the removal of the excess of lime and sodium carbonate, as well as the last traces of calcium and magnesium, in a lime-soda softened water. The removal of ammonia and ammonium salts from boiler feed water, and of iron, manganese, lead, copper, zinc, or other objectionable cations from drinking water, can also be effected by use of these resins.

By the consecutive use of phenolic and amino-resins it is possible to effect complete removal of dissolved salts from solution, yielding a filtrate equipment to distilled water. This has been proved for tap-water using first one type of resin which removed the cations, and then another which completed the purification, the total solids being found to be reduced from 33 parts to about 1 part per 100,000. The two types of resins might be applied to the treatment of trade effluents, both for the purification of such liquors, and for the economic recovery of small amounts of inorganic and organic substances.—(*Int. Sugar Jr.*, Vol. XXXVII, No. 442, p. 407, 1935).

* *I.S.J.*, 1935, p. 259.

* * *

Formulae for translating Sugar into Terms of "Raw Value."

Section 9 (*d*) (6) (*G*) of the Agricultural Adjustment Act, as amended, provides as follows:

"The term 'raw value' means a standard unit of sugar testing ninety-six sugar degrees by the polariscope. All taxes shall be imposed and all quotas shall be established in terms of 'raw value' and for purposes of quota and tax measurements all sugar shall be translated into terms of 'raw value' according to regulations to be issued by the Secretary, except that in the case of direct-consumption sugar produced in continental United States from sugar beets the raw value of such sugar shall be one and seven one-hundredths times the weight thereof.

"I find that, in order to obtain 100 lb. of refined cane sugar, testing by the polariscope 99.8 sugar degrees and above, it is necessary to use 107 lb. of sugar raw value, *i.e.*, sugar testing by the polariscope 96 sugar degrees, and that the raw value of 1 lb. of refined sugar testing by the polariscope 99.8 sugar degrees or above is, therefore, 1.07 lb. I also find that the lb. of sugar raw value to be added for each degree (and fractions of a degree in proportion) of polarization, from 96 degrees to 100 degrees, is to be determined by the formula $\frac{1.07 - 1.00}{100 - 96}$ and is 0.0175 lb.

"I find that the most accurate method for translating any quantity of sugar testing by the polariscope less than 96° into terms of raw value is to find what weight of sugar raw value will have the same weight of total sugar content as such quantity of sugar. I further find that the total sugar content per lb. of 96° sugar (*i.e.* raw value sugar) is 0.972 lb. I, therefore, find that the raw value of any sugar testing less than 96° by the polariscope is to be determined by dividing the number of lb. of the total sugar content thereof by 0.972 lb.

"I do hereby prescribe that, in determining the total sugar content of any sugar, the amount of the sucrose (Clerget) and of the reducing or invert sugars contained therein shall be ascertained in the manner prescribed in paragraphs 758, 759, 762, and 763 of the United States Customs Regulations (1931 edition) or in the manner prescribed on pages 367 to 383, inclusive, of Official and Tentative Methods of the Association of Official Agricultural Chemists (1930 edition)". —(*Int. Sugar Jr.*, Vol. XXXVII, No. 442, pp. 407-08, 1935.)

TREND OF THE MARKETS.

[The notes below are based principally upon running charts of the prices of the basic grades and upon general statistical information gleaned from contemporary publications and cablegrams and are intended to be a record of movements. An attempt is made, where possible, to indicate the market outlook at the time of going to press, but no responsibility for the accuracy and subsequent truth of such observations is assumed. Unless otherwise stated the prices quoted are spot, London.]

SUGAR.—Prices on the Home Markets have ranged as follows (c.i.f. per cwt.) :—

	Foreign.		*Preferential.*	
	s.	*d.*	*s.*	*d.*
26th September ..	4	6	8	3
3rd October ..	4	9	8	6
10th October ..	4	9¾	8	6½
17th October ..	5	0	8	9
24th October ..	5	0	8	9
31st October ..	4	11¼	8	7¼
7th November ..	4	10½	8	7½
14th November ..	4	9¾	8	6¾
(*15th November*, 1934)	3	11¼	7	8¼

Following upon the reaction reported in our last issue the tone of the market has generally remained firm. This has in a large measure been due to the uncertainties surrounding the European situation. Considerable progress has, however, been made towards statistical equilibrium and this also is gradually turning sentiment in favour of the market. With world consumption showing a steady if moderate expansion and the help of a more liberal stock policy on the part of distributors, a further improvement would be witnessed.

* * *

RUBBER.—Quotations for Plantation Sheet have ranged as follows :—

	Pence per lb.
25th September	5 11-16
2nd October	5 11-16
9th October	6
16th October	6 1-4
23rd October	6 3-8
30th October	6 1-2
6th November	6 7-16
13th November	6 5-16
(*14th November*, 1934) ..	6 3-8

There has been an appreciable rise in rubber prices brought about by an improvement in demand from the Continent and the Home trade and also by the news that the Dutch East Indies Government had authorised the Department for Economic Affairs to purchase rubber export licences to an amount of 20,000 tons, in order to counteract the excess of native rubber exports over the permissible exportable amount. U.S.A. Consumption figures for September are estimated at 37,553 tons, total consumption for first nine months of the year at 368,993 tons.

* * *

BANANAS.—There has been a slight improvement in the demand, Jamaicas being £1 per ton higher at £17 5s. per ton delivered London and £17 nearest station. Brazilians are quoted at £13 10s. per ton or 10s. per ton lower.

COTTON.—The following are the official spot prices in pence per lb. of the Liverpool Cotton Association :—

	American Mid.	*Egyptian F.G.F. Sakel.*
27th September	6.40	8.52
4th October	6.59	8.70
11th October	6.50	8.67
18th October ..	6.40	8.88
25th October	6.47	—
1st November	6.42	—
8th November	6.41	—
15th November ..	6.77	—
(*12th November*, 1934) ..	6.88	8.80

Demand for raw cotton has been fairly active and the opinion is generally held that prices are not likely to fall appreciably in the near future. The crop in U.S.A. will probably be 11,500,000 bales. Sea Island Cotton is in good demand with prices very firm and ranging chiefly from 17*d.* to 18*d.* for white cotton.

* * *

COCOA.—During the early part of this month the cocoa market has been very quiet, but notwithstanding this, prices of Accra have been quoted rather higher. On advices from the Coast the price was quoted at 22*s.* c.i.f. London, with shippers even quoting 22*s.* 6*d.* Good fermented *ex* warehouse is quoted at 23*s.* to 23*s.* 3*d.* These high prices which have been occasionally quoted have left buyers quite indifferent. They remain impressed by the fact that large quantities of new crop should shortly be available. Locally $6.00 a fanega is paid for Plantation Cocoa.—(*By Courtesy of the Cocoa Planters' Association of Trinidad, Ltd.*).

* * *

COFFEE. The market is about steady, latest prices quoted include Blue Mountain Jamaica, bold size, at from 130*s.* to 163*s.* and second size at 110*s.* for fairly good and 90*s.* for poor quality ; Santos Superior 36*s.* 3*d.*, Costa Rica good to fine 70*s.* to 105*s.*, Kenya good to fine 95*s.* to 105*s.*, ordinary 40*s.* to 45*s.*

* * *

COPRA.—Copra is dearer, West Indian f.m.s. having risen from £12 5*s.* 0*d.* per ton to £14 5*s.* c.i.f.

* * *

LIME PRODUCTS.—*Lime Oil.*—Small sales of Handpressed have been made at 37*s.* 6*d.* per lb. *ex* wharf London. Distilled is firm at 22*s.* 6*d.* *Lime Juice.* No general interest is being shown in Concentrated. Raw is steady but quiet with the last quotations of 2*s.* to 2*s.* 6*d.* for good to fine unchanged.—(*West India Committee Circular*, 24th October, 1935.)